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I/ITSEC DIS Interoperability Demonstration Test Procedures And Results

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INSTITUTE FOR SIMULATION AND TRAINING

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I/ITSEC DIS INTEROPERABILITY DEMONSTRATION TEST PROCEDURES AND RESULTS

PREPARED FOR:
U.S. Army Simulation Training And Instrumentation Command
12350 Research Parkway
Orlando, Florida 32826-3276

DISTRIBUTED INTERACTIVE SIMULATION
INDUSTRY GOVERNMENT ACADEMIA DIS

IST

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Division of Sponsored Research

IST-TR-93-04

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Distributed Interactive Simulation
Testbed

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1. INTRODUCTION

In March 1992, the concept for a real-time demonstration of the Distributed Interactive Simulation (DIS) standard was conceived for the 14th Interservice/Industry Training Systems Education Conference (I/ITSEC) held in San Antonio, Texas on 2-5 November 1992. This effort 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 data bases 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 data bases.

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 clearinghouse for interested parties desiring more information, wishing to participate, or needing help with specific technical aspects of the effort.

1.1 Purpose

The concept of interoperability in networked simulation is difficult to define. For the purposes of the I/ITSEC demonstration, interoperability was defined as the ability of the participating systems to:

a) Connect to a common network. This connection included the ability to send information about a simulated entity's state to other simulations on the network. It also included a simulation system's ability to obtain information from the network containing state information about simulated entities controlled by other network simulation systems.

b) Interpret incoming information. Systems must be able to make sense of the state information received from the network. This required using a standard data format for sending and interpreting information. These formats are described in the DIS PDU standard.

c) Recreate a portion of the simulated world. Using the resources of its own simulation and information received from the network, a system must be able to

immediately recreate a picture of the simulated environment. Interoperability in this sense was the most difficult to achieve because different systems may recreate the simulated world in ways that do not correlate.

1.2 Objectives

The objectives of the demonstration were to:

- demonstrate not evaluate,
- keep scope manageable,
- accumulate data,
- analyze results, and
- minimize new development.

1.3 Abbreviations and Acronyms

ARP	Address Resolution Protocol
BAM	Binary Angle Measurement
BBN	Bolt, Beranek, and Newman Systems and Technologies
CGF	Computer Generated Forces
DIS	Distributed Interactive Simulation protocol standard
DMA	Defense Mapping Agency
ES	Entity State
E&S	Evans & Sutherland
GD	General Dynamics
IBM	International Business Machines
ICMP	Internet Control Message Protocol
IDA	Institute for Defense Analysis
IEEE	Institute for Electrical and Electronic Engineers
I/ITSEC	Interservice/Industry Training Systems and Education Conference
IG	Image Generator
IP	Internet Protocol
ISF	Intelligent Simulated Forces
IST	Institute for Simulation and Training
NRaD	Naval Research and Development
NTC	Naval Training Center
NTSC	Naval Training Systems Center
PC	Personal Computer
PDU	Protocol Data Unit
PRC	Planning Research Corporation
PVD	Planview Display
SAF	Semi-Automated Forces

SIF	Standard Interchange Format
SIMNET	Simulator Network protocol standard
STRICOM	U.S. Army Simulation Training and Instrumentation Command
SUT	System Under Test
TDB	Terrain Data Base
TSI	Technology System Incorporated
UAV	Unmanned Air Vehicle
UDP	User Datagram Protocol
UTM	Universal Transverse Mercator
USAF	United States Air Force
USGS	United State Geological Survey

2. 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" (see Appendix A) which was distributed to all participants within two weeks of the last planning meeting by *e-mail*, fax, or mail. The planning meetings took place over a period of seven months. In concurrence with several meetings, tutorials were held on different components of the demonstration. The meeting dates were: 18 March, concurrently with the 6th DIS workshop; 10 April; 19 May; 23 June; 24 June, concurrently with a SIF tutorial; 29 July; 20 August; 21 August, concurrently with a UDP/IP tutorial; and 23 September, concurrently with the 7th DIS workshop.

2.1 General

Over the 8 month period, 28 organizations directly supported and/or participated in the planning meetings and demonstrations. Participants were polled periodically about the types of simulators they would bring to Texas. The numbers and types of simulators varied from meeting to meeting. In the end, there were a total of 18 Send/Receive (S/R) devices (manned simulators and CGF), 22 Receive Only (RO) devices (network monitors, Stealths, etc.), and 1 Send Only (SO) 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 S/R devices, 4 were CGF systems. The organizations and types of simulators which participated in the demonstrations are shown in Table 1. In addition to simulator participation, the planning meetings and demonstration were supported by STRICOM, USAF ASD, DMSO, USAF, PRC, Armstrong Labs, Evans & Sutherland, and Star Technologies.

COMPANY NAME	TYPE OF SIMULATOR	MODE OF OPERATION
Loral/GE	M1 Tank	S/R
	Live M1	S/R
	Taper	SO
	Plan View Display	RO
Grumman	E2C	S/R
TSI	Stealth	RO
IST	CGF	S/R
	Network Monitor	RO
	Data Logger	RO
	Stealth	RO
CAE Link	AH-64	S/R
	Stealth	RO
	Data Logger	RO
	Data Logger	RO
NTSC	F/A-18	S/R
	Surface Ship	S/R
BBN	PVD	RO
	CGF	S/R
	Stealth	RO
Hughes	UAV	S/R
	JSTARS	RO
IDA	Stealth	RO
	Data Logger	RO
	PVD	RO

Table 1: I/ITSEC Demonstration Participants
S/R = Send/Receive; SO = Send Only; RO = Receive Only

COMPANY NAME	TYPE OF SIMULATOR	MODE OF OPERATION
Lockheed-Sanders	TSAD Scenario Monitor Patriot	RO RO S/R
McDonnell Douglas	F16/SAM Sites Network Monitor	S/R RO
IBM/ECC	After Action Review Battle Master M1	RO S/R S/R
NRaD	LHD Surface Ship Stealth	S/R RO
Motorola	Surface Ship	S/R
GD Land	M1	S/R
GD Air	F16	S/R
Rockwell	F16	S/R
Reflectone	Radar	RO
SG/Mak	Stealth	RO
Concurrent	Network Monitor	RO

Table 1 (Cont'd): I/ITSEC Demonstration Participants
S/R = Send/Receive; SO = Send Only; RO = Receive Only

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. Testing and integration took place in the Gallery Hall of the San Antonio Convention Center.

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 Ida 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.

IST coordinated development of the scenario for the formal demonstrations. The scenario was designed to provide a setting to demonstrate the capabilities of the participant's networked simulators without fear of intentional or inadvertent destruction by another player. To reduce the possibility of danger to any individual simulator, a table of lethality was designed by IST and tested to ensure that individual players could not be destroyed by other "friendly" or "OPFOR" players.

The participants decided in early planning meetings to make the network public. Anyone could play on the network as long as he or she did not interfere with any other player on the network. The decision to develop a mutually beneficial network was based on the position to "demonstrate not evaluate" the DIS Interoperability Network.

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

2.2 Network Design

The network design for the I/ITSEC demonstration consisted of two parts: one network for testing simulator interoperability during the seven months prior to leaving for Texas 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 known DIS compliant system. 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.

2.2.1 DIS Testbed

IST, under contract to STRICOM, is designing, developing, and implementing a DIS testbed which provides verification of the DIS standards process, provides a tool for DIS implementers, and functions as a standing demonstration mechanism which facilitates the promulgation and expanded use of DIS. The objectives of the testbed are to hasten the use of networking in real-time simulation and to reduce the risk associated with the introduction. In particular, IST is interested in research involved with the performance, evaluation, and optimization of DIS PDUs and communication services in actual real-time simulation. The testbed is based on a modular design and uses commercial-off-the-shelf (COTS) components to the maximum extent possible. Initial capabilities of the testbed were demonstrated at I/ITSEC in November.

Currently, the testbed is a thin Ethernet network connecting the SIMNET equipment (2 M1 simulators, MCC, Stealth, PVD, data logger, and BBN CGF) on loan to IST, the IST developed CGF and data logger, a TSI DIS/SIMNET protocol translator, a TSI portable Stealth, and a NetBlazer for long haul connection[1]. The DIS testbed is shown in Figure 1.

The testbed supports a variety of communication protocols. Any of the eight combinations (see Section 3.2.1.1.3 for the eight combinations) of the following protocols can be accommodated:

- DIS PDUs or SIMNET PDUs,
- SIMNET association protocol or null,
- User Datagram Protocol (UDP)/Internet Protocol (IP) or null, and
- IEEE 802.3 (CSMA/CD) or Ethernet 2.0.

In the future, the testbed will support FDDI and OSI protocols.

[1] Future versions of the network will include a laser or microwave link to the Defense Simulation Internet (DSI) through STRICOM.

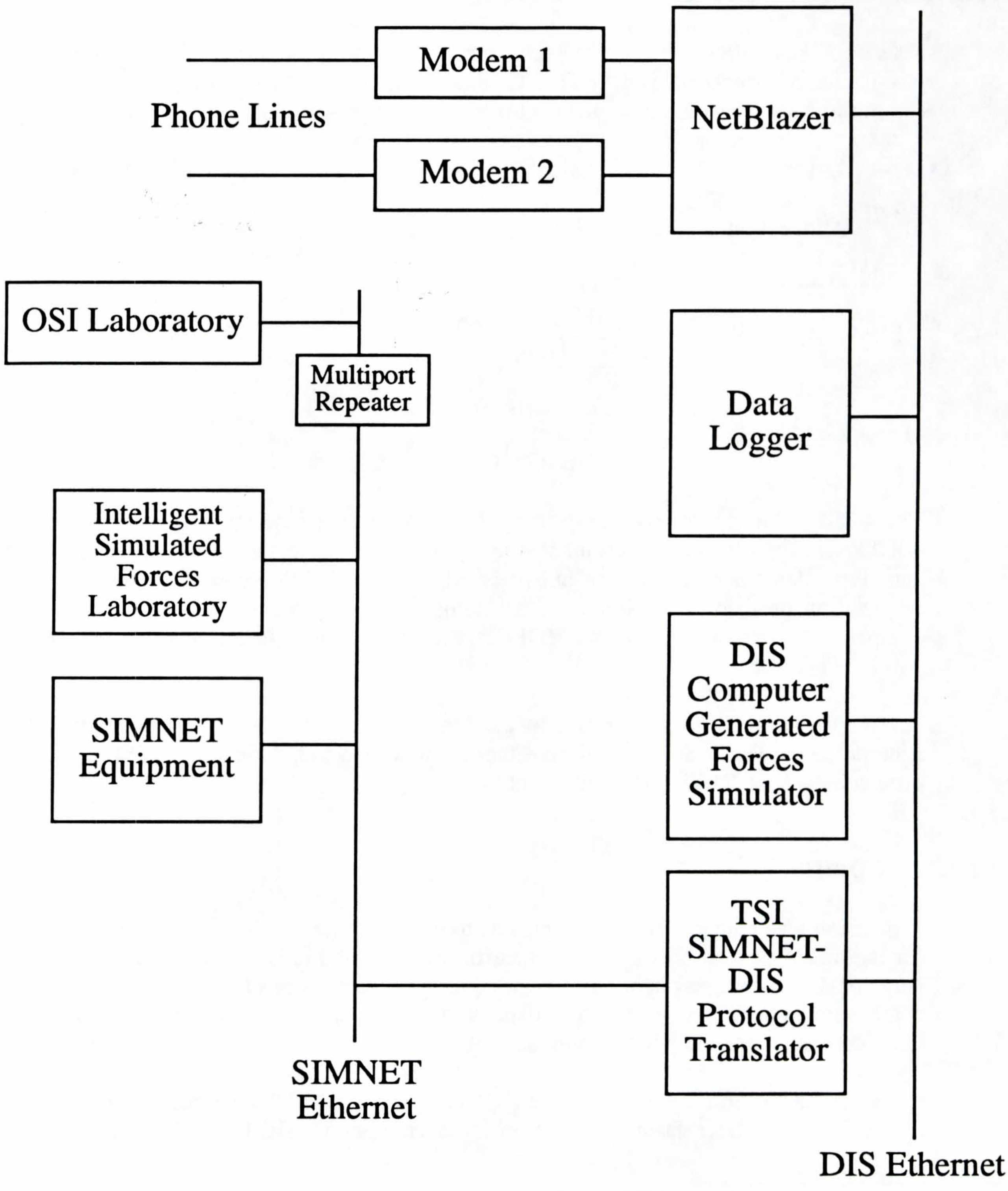


Figure 1: DIS Testbed

2.2.1.1 Communication Protocols

As stated above, IST's testbed can accommodate a variety of communication protocols. 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
a)	Application	DIS
b)	Network[2]	UDP/IP SIMNET Association CLTP/CLNP Null
c)	Link[3]	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.

2.2.1.1.1 UDP/IP

A decision was reached by the participants to use IP broadcast during the demonstration for legitimate simulation traffic. DIS traffic was directed to UDP port 3000 (decimal). Any non-DIS messages put on the network during demonstrations (e.g., operator interface data) were to be sent point-to-point if possible and, if that was not possible, multicast. Each company was assigned 10 unique UDP port numbers for non-DIS traffic.

IST made no recommendations for the UDP source port (the UDP source port is defined, in RFC 768 - "User Datagram Protocol" as an optional field). IST also made no

[2] The Transport and Network Layers are combined as "network."

[3] The Data link and Physical layers are collectively called "link."

recommendation as to whether the UDP optional checksum should be computed or should be sent as zero (see RFC 768). Because simulation PDUs do not require IP fragmentation, there should have been no fragmented IP traffic to UDP port 3000.

Class B IP addresses were used for the demonstration. The network number (the first two octets) was selected to be 132.170 (i.e., IST's network number). Each company was assigned unique host numbers. IST requested that hosts be numbered sequentially starting at 1 (e.g. 132.170.103.001, 132.170.103.002, and so on). The IP addresses and UDP port numbers assigned to participants are shown in Table 2.

Broadcast transmission for DIS data was sent to address: 132.170.255.255.

2.2.1.1.2 IST's UDP/IP Implementation

Some of the I/ITSEC participants used commercial versions of UDP/IP, but IST chose to do a custom installation. The effort was engaged for several reasons:

- Because UDP/IP is a datagram protocol, its implementation is straight forward. The cost of implementation is mitigated by the gained knowledge which can be then applied to future projects. Simply buying a UDP/IP implementation would have given IST no useful insights into UDP/IP issues.

- IST, having done the UDP/IP implementation, was able to assist other participants who chose to do custom implementations. This was manifested when IST held a two hour colloquium on 21 August 1992 describing the techniques for protocol implementations in general, and UDP/IP in particular.

- The IST CGF Testbed simulators were among the slowest machines to appear at I/ITSEC. A custom implementation would allow the best chance of achieving maximum throughput.

- The architecture of the CGF Testbed was not amenable to integration with commercially available packages. With IST's implementation of communication protocols, it was easy to select different combinations at link time (See Section 2.2.1). This may have been practical with a commercial product but was simple and natural using a design targeted for this system. A report detailing IST's implementation of UDP/IP/Ethernet can be found in Reference [3].

IP ADDRESS	PARTICIPANT	UDP PORT NUMBERS
132.170.100.xxx	Loral/GE	300x[4]
132.170.101.xxx	Grumman	301x
132.170.102.xxx	TSI	302x
132.170.103.xxx	IST	303x
132.170.104.xxx	CAE-Link	304x
132.170.105.xxx	NTSC	305x
132.170.106.xxx	BBN	306x
132.170.107.xxx	Hughes	307x
132.170.108.xxx	Not Used	
132.170.109.xxx	IDA	309x
132.170.110.xxx	Lockheed	310x
132.170.111.xxx	McDonnell Douglas	311x
132.170.112.xxx	IBM/ECC	312x
132.170.113.xxx	NRaD	313x
132.170.114.xxx	Motorola	314x
132.170.115.xxx	GD Land	315x
132.170.116.xxx	GD Ft. Worth	316x
132.170.117.xxx	Rockwell	317x
132.170.118.xxx	Reflectone	318x
132.170.119.xxx	Silicon Graphics	319x
132.170.120.xxx	Concurrent Computer	320x

Table 2: IP Addresses and UDP Port Numbers

2.2.1.1.3 ARP

Because all simulation traffic was broadcast, no Address Resolution Protocol (ARP) requests were expected relating to the simulation itself; however, it was strongly recommended that all systems implement ARP for the purpose of testing network integrity. The purpose of ARP is to determine the physical (i.e., Ethernet) address associated with a known IP address. For testing prior to the demonstration, IST generated an ARP packet containing a broadcast Ethernet address and the unique IP address of each simulator. Each simulator would receive the packet (i.e., broadcast Ethernet address) and only the target simulator (i.e., unique IP address) would respond by transmitting its unique Ethernet address. This would ensure that IST could send and receive with each simulator.

[4] Loral/GE port numbers are 3001-3009.

2.2.1.2 Long Haul Connection to IST

A long haul connection was established to assist the participants with dialing-in to IST to test their DIS simulators. The long haul facility not only supported the I/ITSEC demonstration pre-testing but also provided a convenient medium for users to continue to experiment with DIS applications.

IST had two options for a long haul connection: leased lines or public switched network. Several factors determined the choice for a long haul connection: 1) simplicity of implementation, 2) ease of learning, using, and training personnel, 3) ability of remote users to configure their implementations in a short period of time in order to make a connection to the testbed, and 4) effectiveness of cost.

The first option, leased lines, would have utilized two identical routers at each destination connected by a leased line. If high data rates had been required there would have been a definite advantage to this approach because it is a dedicated point-to-point connection. However, the major disadvantage was that the sender and the receiver must use the same router. Also, monthly costs for leased lines can be high. Consequently, there was no support from I/ITSEC participants to pay for leased line capability. Therefore, this option was deemed restrictive and not cost effective.

The second option, a public switched network, would consist of two modems and a gateway device. The modems need not be the same brand and the transmission speed of the modems could be selected by the users. Only one gateway device was required and was cost effective compared to the cost of a router. The connection was established through the public phone network which charges the user by the minute rather than by a monthly fee. This option was cost effective and gave the users flexibility in choosing COTS equipment.

IST chose to implement the second option, consequently, purchasing two TELEBIT T3000 modems with transmission speeds of up to 57.6kbps and V32bis modem capabilities. The NetBlazer was selected as the gateway device. It functions by interfacing serial line protocols with Ethernet protocols. The NetBlazer's routing function makes it a flexible tool for integrating a large number of remote users and networks into a wide area network. The NetBlazer routes packets to remote users who call in with TCP-UDP/IP communication software. The TCP-UDP/IP software must support one of the two serial line protocols, Serial Line IP (SLIP) or Point-to-Point Protocol (PPP). Two toll free phone lines were also installed for testing purposes. Communication using the telephone lines with packetized data makes the simulator calling-in an actual node on the IST network. With this design, the DIS testbed can accommodate two remote users at one time. See Figure 2 for the hardware configuration of the long haul link. A detailed description of the IST long haul connection can be found in Reference [2].

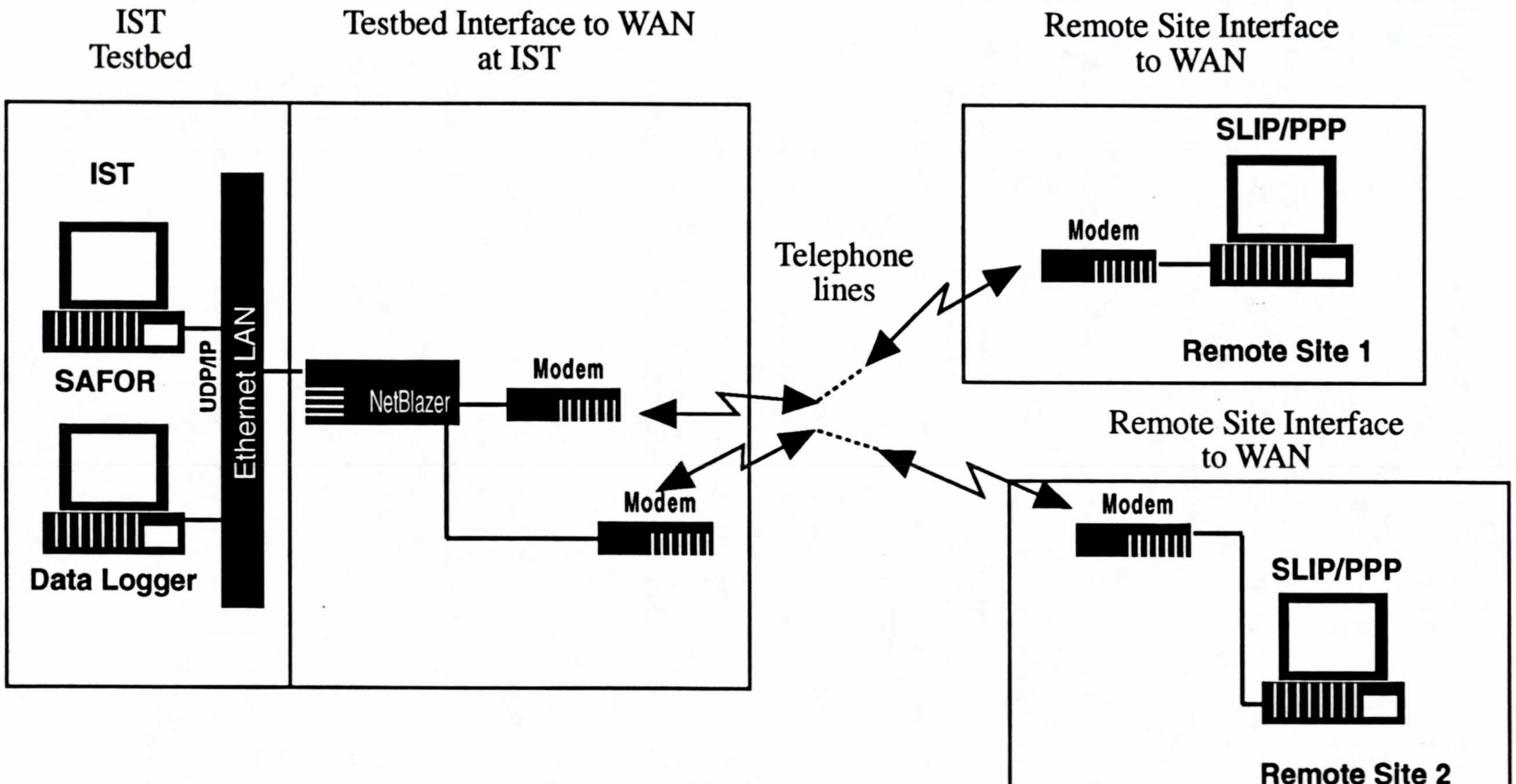


Figure 2.

Hardware Configuration for the Long Haul Connection

To gain access to the IST testbed, the computer/simulator must be running SLIP or PPP. To dial into IST use the following telephone numbers:

1)	1-800-226-5042	(voice)
2)	1-800-226-5023	(data)
3)	1-407-658-5512	(lab phone)

Testing can be performed for both one or two participants.
For one participant individually, use phone line #1 for voice and phone line #2 for data.
With two participants, use both phone lines for data.

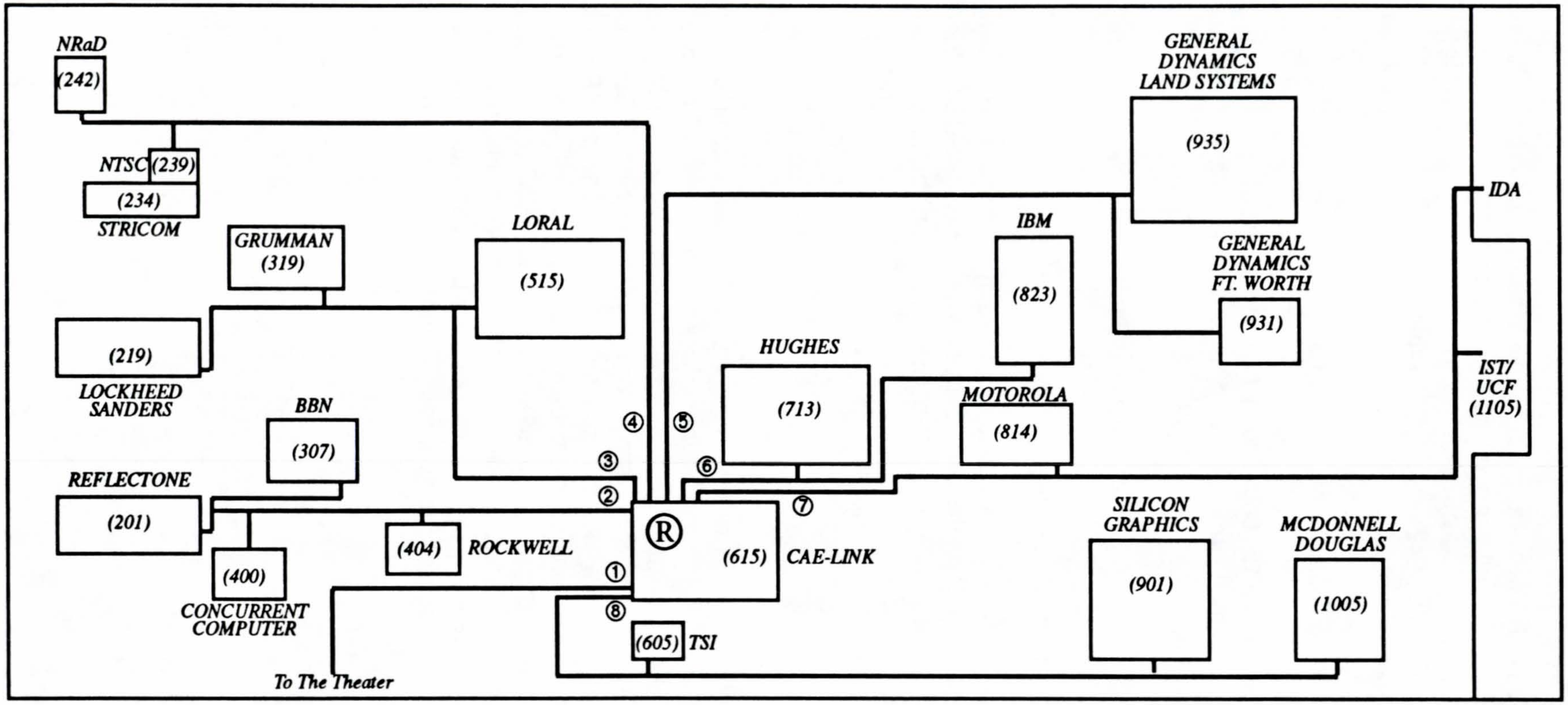
Remote users will get the following "login" prompt:

NetBlazer login:

Separate login and passwords are assigned to each participant. Once connected, the participant becomes a node on the IST testing network. Because UDP/IP broadcast mode is used for testing, each node on the network receives all broadcasted PDUs. At this point, testing starts.

2.2.2 Demonstration Network

Two demonstration networks were implemented at the San Antonio Convention Center. The first network was established during the rehearsal week. This network had two configurations. At the beginning of the week it connected all participants using a star topology; at the end of the week, three subnetworks were created for land, sea, and air entities. The participants who had more than one type of simulator (i.e., land, sea, and air) were given connections to more than one network. The second network was established when the participants moved to the southeast exhibit hall. This network was used for the formal exercises, the free play, and the 30 minute time slots. The main configuration of the network was a star topology which consisted of eight branches with a repeater at the main hub of the network. Figure 3 depicts the routing layout.



® = REPEATER

Figure 3

I/ITSEC Demonstration Network

2.2.2.1 Hardware Configuration

The hub of the second network was a multiconnect repeater located in the CAE-Link booth. This equipment was a modular, IEEE 802.3 compatible, multiport repeater that provided a flexible central platform for multisegment, multimedia Ethernet networks. This repeater allowed Ethernet segments to be connected in a bus, a star, or both bus and star configurations. The network configuration used for the I/ITSEC demonstration involved both bus and star topologies. With this configuration, signals from each segment were repeated to all other segments, so the Ethernet network could reach more users. Faulty segments could be partitioned and reconnected once the fault was eliminated. The multiconnect repeater also provided a centralized network management hub that simplified the isolation of problems.

Thin Ethernet cables were used along with barrel connectors, T-connectors, and 50 ohm terminating resistors. T-connectors were used to provide the BNC interfaces to participant's booths. Participants used these BNC connectors to access the main network. If the participants had one simulator, then the interface provided by IST connected directly to the Ethernet card of that simulator. However, most of the participants had their own local area network within their booth. In this situation, because of the IEEE standards for thin Ethernet, a repeater, router, or bridge had to be placed between the BNC interface and the participant's network in order to prevent network failures. The IEEE 802.3 standard states the following:

1) There is a null distance between the BNC interface and the Ethernet card; and

2) There is a distance limitation of thin Ethernet cables, which is approximately 607 feet.

Therefore, by placing a repeater, router, or bridge in between the BNC connector and the Ethernet card, it was possible to eliminate the cable length problem (assuming the cable in each participant's booth was less than 607 feet). The majority of participants used repeaters inside their booths to connect to the demonstration backbone; however, several participants used bridges and routers.

2.2.2.2 Network Tools

Several network tools were used for testing and monitoring the network. The first tool was an HP network analyzer which was used in two roles. First, it was used to check whether any traffic was on the network. Second, the analyzer was pre-programmed with the Ethernet addresses of all the participants. Using this function, it was possible to specifically evaluate the functionality of each leg of the star topology.

The multiconnect repeater also had diagnostic capabilities. The status indicator and manual segment partitioning indicators allowed diagnosis and resolution of network problems. For example, if the status indicator was not blinking, then that meant the particular segment was not functioning.

2.3 DIS Standard

The DIS standard used in the demonstration was Version 1.0 dated 8 May 1991. 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. See Section 2.3.2. In addition to these restrictions, a set of policies were 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 to it. 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.

2.3.1 Protocol Data Units

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.

There were two clarifications made in the Entity State PDU. First, a relative timestamp was to be used in place of an absolute timestamp because of the absence of a global network timing mechanism. This required the least significant bit in the 32-bit timestamp field to be set to one. Second, in the articulation parameter record, the 64-bits articulation parameter value field was to be used to indicate the turret azimuth and gun elevation. Of the 64-bits, only the first 32-bits were used, and the remaining 32-bits were padded with zeros. Articulation parameters were only used on some of the ground based vehicles, like the M1A1, M1A2, M2, T72, and BMP1. The remainder of the allowed entity types and munitions would have no articulated parameters.

In the case of the Detonation PDU, no articulation parameters were present in the PDU since no damage models were used in the DIS demonstration. Damage assessment models were excluded to reduce the complexity of the exercise.

2.3.2 Policies

The goal of the formal exercise was to demonstrate DIS and to keep that exercise as simple as possible. As mentioned above, certain policies were negotiated to keep the scope of the demonstration simple and manageable. With this in mind, the participants agreed to the following policies:

- The entity types and their 64-bit entity type record is listed below in Table 3;
- The munition types and their 64-bit entity type record is listed below in Table 4;
- In order to accommodate new entity and munition types that were not defined in Appendix H of the DIS standard, a new entity type record was assigned to each. These were the M1A2, JSTARS, and UAV for the entity types and the Penguin, RPG16, M203, 23mm HEI, 73mm, 125mm HEAT, 125mm KE, 57mm rocket, 2.75 inch A/G rocket, MK82, MK84, and 550Kg bomb for the munition types;
- In order to promote consistency across participating simulation applications, IST produced a munition type versus entity type kill matrix. The "x" in the matrix means a "kill" on hit result. See Table 5;
- For dismounted infantry (DI) group representation, it was agreed that the DI entity would represent a 5 man fire team. This was indicated in the specific field of the entity type record. See Table 3;
- IST assigned a unique Site ID to each participating company while the assignment of host ID was left to the company's discretion. See Table 6;
- The exercise ID would be set to 1 during the demonstration;
- The bit ordering defined in Section 5 of the DIS standard was not used. The bit ordering used in the demonstration was defined with bit zero to be the least significant bit;
- To identify between the two forces, the force ID was assigned 1 (brown) to be the friendly force and 2 (green) to be the opposing force. To ensure a win-win scenario, BBN volunteered their CGF to be the opposing force, and all other entities would be friendly forces;

- Because no damage models were used in the demonstration, no articulation parameters were present in the Detonation PDU; and

- A first degree dead reckoning model was used. Because only the first order was used, no dead reckoning parameters were needed, except for the algorithm field with value of two. It was decided that the threshold for issuance of new Entity State PDUs was 3 degrees and 1m cubic.

ENTITY TYPES: FIELD VALUES FROM APPENDIX H1 AND H2 (06/05)

TYPE	KIND	DOMAIN	COUNTRY	CATEGORY	SUBCAT	SPECIFIC	EXTRA	# Art. Part
M1A1	PLATFORM 1	LAND 1	USA 168	TANK 1	1	1	0	2
M1A2	PLATFORM 1	LAND 1	USA 168	TANK 1	1	2	0	2
M2	PLATFORM 1	LAND 1	USA 168	ARMORED 2	3	0	0	2
T-72	PLATFORM 1	LAND 1	USSR 164	TANK 1	2	1	0	2
BMP-1	PLATFORM 1	LAND 1	USSR 164	ARMORED 2	1	0	0	2
PATRIOT RADAR	PLATFORM 1	LAND 1	USA 168	MISC 51	0	0	0	0
PATRIOT Launcher	PLATFORM 1	LAND 1	USA 168	TOW ARTIL 5	0	0	0	0
PATRIOT STATION	PLATFORM 1	LAND 1	USA 168	L.W UT VEH 7	0	0	0	0
E-2C	PLATFORM 1	AIR 2	USA 168	ELECT WAR 53	1	0	0	0
F/A-18	PLATFORM 1	AIR 2	USA 168	FIGHTER 1	14	0	0	0
F-14DF	PLATFORM 1	AIR 2	USA 168	FIGHTER 1	2	4	0	0
F-15	PLATFORM 1	AIR 2	USA 168	FIGHTER 1	7	0	0	0
F-16C	PLATFORM 1	AIR 2	USA 168	FIGHTER 1	3	3	0	0
F-16D	PLATFORM 1	AIR 2	USA 168	FIGHTER 1	3	4	0	0
A-10	PLATFORM 1	AIR 2	USA 168	ATTACK 2	4	0	0	0
FrogFoot SU-25	PLATFORM 1	AIR 2	USSR 164	ATTACK 2	8	0	0	0
APACHE AH64	PLATFORM 1	AIR 2	USA 168	ATT HELIC 6	1	0	0	0
HIND MI-24	PLATFORM 1	AIR 2	USSR 164	ATT HELIC 6	2	0	0	0
BLACK HAWK	PLATFORM 1	AIR 2	USA 168	UTIL HELIC 7	2	0	0	0
SH-60	PLATFORM 1	AIR 2	USA 168	SEA HELIC 52	3	0	0	0
JSTARS	PLATFORM 1	AIR 2	USA 168	ELECT WAR 53	6	0	0	0
E-3A	PLATFORM 1	AIR 2	USA 168	ELECT WAR 53	4	1	0	0
Umanned Air Veh	PLATFORM 1	AIR 2	USA 168	U A V 54	0	0	0	0
BEAR TU-142	PLATFORM 1	AIR 2	USSR 164	BOMBER 3	5	0	0	0
BACKFIRE TU-26	PLATFORM 1	AIR 2	USSR 164	BOMBER 3	3	0	0	0
AEGIS FFG 7	PLATFORM 1	SURFACE 3	USA 168	G.M.FRIGAT 6	1	1	0	0
H CARRIER WASP	PLATFORM 1	SURFACE 3	USA 168	AM.AS.SHIP 54	3	0	0	0
U.S.- D.I.	LIFE FORM 3	LAND 1	USA 168	DISM INFANT 1	0	5	0	0
USSR - D.I.	LIFE FORM 3	LAND 1	USSR 164	DISM INFANT 1	0	5	0	0

Table 3: Entity Types

TYPE	KIND	DOMAIN	COUNTRY	CATEGORY	SUBCAT	SPECIFIC
SPARROW AIM-7	MUNITION 2	ANTI-AIR 1	USA 168	GUIDED 1	13	0
AMRAAM AIM-120	MUNITION 2	ANTI-AIR 1	USA 168	GUIDED 1	2	0
PHOENIX	MUNITION 2	ANTI-AIR 1	USA 168	GUIDED 1	13	0
SIDE-WINDER	MUNITION 2	ANTI-AIR 1	USA 168	GUIDED 1	1	0
STINGER	MUNITION 2	ANTI-AIR 1	USA 168	GUIDED 1	15	0
MAGIC	MUNITION 2	ANTI-AIR 1	FRANCE 55	GUIDED 1	9	0
PATRIOT	MUNITION 2	ANTI-AIR 1	USA 168	GUIDED 1	16	0
SA7 GRAIL	MUNITION 2	ANTI-AIR 1	USSR 164	GUIDED 1	18	0
SA9 GASKIN	MUNITION 2	ANTI-AIR 1	USSR 164	GUIDED 1	20	0
HELLFIRE	MUNITION 2	A-ARMOR 2	USA 168	GUIDED 1	3	0
TOW	MUNITION 2	A-ARMOR 2	USA 168	GUIDED 1	1	0
MAVERICK AGM-65	MUNITION 2	A-ARMOR 2	USA 168	GUIDED 1	4	0
SPIRAL AT-6	MUNITION 2	A-ARMOR 2	USSR 164	GUIDED 1	8	0
Spandrel AT-5	MUNITION 2	A-ARMOR 2	USSR 164	GUIDED 1	7	0
HARM	MUNITION 2	A-RADAR 4	USA 168	GUIDED 1	1	0
PENGUIN	MUNITION 2	A-SHIP 6	USA 168	GUIDED 1	9	0
HARPOON	MUNITION 2	A-SHIP 6	USA 168	GUIDED 1	1	0
DRAGON	MUNITION 2	A-ARMOR 2	USA 168	GUIDED 1	2	0
RPG-16	MUNITION 2	A-ARMOR 2	USSR 164	GUIDED 1	11	0
Grenade. for M203	MUNITION 2	A-Person 1	USA 168	Ballistic 2	10	0
5.56 mm (SAW/M16)	MUNITION 2	A-Person 1	USA 168	Ballistic 2	1	0
7.62 mm	MUNITION 2	A-Person 1	USA 168	Ballistic 2	2	0
20 mm CANNON	MUNITION 2	BF Support 3	USA 168	Ballistic 2	1	0
23 mm HEI	MUNITION 2	BF Support 3	USA 168	Ballistic 2	21	0
25 mm HEI	MUNITION 2	BF Support 3	USA 168	Ballistic 2	2	0
25 mm KE	MUNITION 2	BF Support 3	USA 168	Ballistic 2	2	0

MUNITION TYPES: FIELD VALUES FROM APPENDIX H2 (06/04)

TYPE	KIND	DOMAIN	COUNTRY	CATEGORY	SUBCAT	SPECIFIC
30 mm	MUNITION 2	BF Support 3	USA 168	Ballistic 2	3	0
73mm	MUNITION 2	BF Support 3	USA 168	Ballistic 2	22	0
105 mm HEAT	MUNITION 2	BF Support 3	USA 168	Ballistic 2	10	0
105 mm KE	MUNITION 2	BF Support 3	USA 168	Ballistic 2	10	0
120 mm KE	MUNITION 2	BF Support 3	USA 168	Ballistic 2	11	0
120 mm CE	MUNITION 2	BF Support 3	USA 168	Ballistic 2	11	0
125 mm HEAT	MUNITION 2	BF Support 3	USA 168	Ballistic 2	23	0
125 mm KE	MUNITION 2	BF Support 3	USA 168	Ballistic 2	23	0
57mm Rocket	MUNITION 2	BF Support 3	USA 168	Ballistic 2	24	0
2.75 inch a/g rocket	MUNITION 2	BF Support 3	USA 168	Ballistic 2	20	0
MK82 BOMB	MUNITION 2	BF Support 3	USA 168	Ballistic 2	18	0
MK84 BOMB	MUNITION 2	BF Support 3	USA 168	Ballistic 2	19	0
550 Kg BOMB	MUNITION 2	BF Support 3	USA 168	Ballistic 2	25	0

Table 4: Munition Types

Matrix of Munition Type x Entity Type (X = Kill)

munition\entity	M1 A1	M1 A2	M2 /M3	T 72	BMP 2	Pat. Rdr.	Pat. Lch.	Pat. CIC	E 2C	F/A 18	F14 D/F	F 15	F 16C	F 16D	A 10	AH 64	MI 24	UH 60	SH 60	JSTARS	E 3A	UAV	SU 25	TU 142	TU 26	FFG 7	LHD 1	US DI	OPFOR DI
SPARROW									X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X				
AMRAAM									X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X				
PHOENIX									X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X				
SIDEWINDER									X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X				
MAGIC									X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X				
PATRIOT									X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X				
SA 7 (GRAIL)									X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X				
SA 9 (GASKIN)									X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X				
HELLFIRE	X	X	X	X	X	X	X	X																				X	X
AT 6 (SPIRAL)	X	X	X	X	X	X	X	X																				X	X
TOW	X	X	X	X	X	X	X	X																				X	X
MAVERICK	X	X	X	X	X	X	X	X																				X	X
HARM						X																							
PENGUIN																										X	X		
HARPOON																										X	X		
DRAGON			X	X	X	X	X	X																				X	X
AT 4 (SPIGOT)			X	X	X	X	X	X																				X	X
RPG-7			X	X	X	X	X	X																				X	X
GRENADE-M203						X	X	X																				X	X
5.56 mm																												X	X
7.62 mm						X	X	X																				X	X
20 mm CANNON			X		X	X	X	X																				X	X
120 mm KE	X	X	X	X	X	X	X	X																				X	X
120 mm CE	X	X	X	X	X	X	X	X																				X	X
23 mm HEI			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			X	X
25 mm HEI			X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			X	X
25 mm KE			X		X																							X	X
30 mm			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			X	X
73 mm			X	X	X	X	X	X																				X	X
105 mm HEAT	X	X	X	X	X	X	X	X																				X	X
105 mm KE	X	X	X	X	X																							X	X
125 mm HEAT	X	X	X	X	X	X	X	X																				X	X
125 mm KE	X	X	X	X	X																							X	X
2.75 in. Rocket	X	X	X	X	X	X	X	X																				X	X
57 mm Rocket	X	X	X	X	X	X	X	X																				X	X
MK82 Bomb	X	X	X	X	X	X	X	X																				X	X
MK84 Bomb	X	X	X	X	X	X	X	X																				X	X
550 kg HE Bomb	X	X	X	X	X	X	X	X																				X	X

Please review, circle any x=kill intersection, and return with rationale for nonconcurrance. Fax to Dan Mullally at (407) 658-5059

Table 5: Entity Type vs. Munition Type Kill Matrix

PARTICIPANT	SITE NUMBER	HOST NUMBERS
Loral	515	5: M1 Tank 5: Live M1 104: Taper 155: Plan View
Grumman	319	1: E2C/Stealth
TSI	605	1: Stealth
IST	1105	4: CGF 6: Network Monitor
CAE Link	615	1: AH-64 2: Listen Only
NTSC	238 239	1: F/A-18 2: Ship
BBN	307	1: Obg3 2: Rhyme 3: MCC-PVD 4: Stealth 5: Obg1
Hughes	713	1: JSTARS 2: UAV
IDA	1104	1: Stealth 2: Logger
Lockheed	219	1: Bridge 2: Mite 3: Spider 4: Mouse 5: WS1 6: Snoopy 7: WS11 8: MPSO25 9: SAFDI1 10: SAFDI2

Table 6: Site and Host IDs

PARTICIPANT	SITE NUMBER	HOST NUMBERS
McDonnell Douglas	1005	1: F16
IBM/ECC	823	1: M1 2: Battle Master 3: After Action Review
NRaD	242	1: Ship 2: Stealth
Motorola	814	1: Ship
GD Land	935	1: Test Code 2: M1A2 3: M1A2 4: Stealth
GD Ft. Worth	931	1: F-16
Rockwell	404	32: Fighter
Reflectone	201:	1: Radar
SG/Mak Technologies	901:	1: Listen Only
Concurrent	401:	1: Network Monitor

Table 6 (Cont'd): Site and Host IDs

2.3.3 Coordinate Conversions

There are several coordinate systems which can be used to describe the position, orientation, and motion of the entities in a simulation exercise. An in-depth study of existing publications referenced four coordinate systems: geocentric, geodetic, topocentric, and universal transverse mercator (UTM) coordinate systems. The following are definitions of the different coordinate systems used in today's simulators:

Geocentric: An earth-fixed coordinate system with the origin at the centroid of the earth, the x-axis passing through the prime meridian at the equator, the y-axis passing through 90 degrees east longitude at the equator, and the z-axis passing through the North Pole;

Topocentric: Coordinates whose origin is on the earth's surface and aligned at the selected point with east, north, and up, as distinguished from geocentric coordinates whose origin is at the center of the earth;

Geodetic: The quantities of latitude, longitude, and height (ellipsoid), which define the position of a point on the surface of the earth with respect to the reference spheroid; and

UTM: A map projection and grid system adopted by the U.S. Army in 1947 for designating rectangular coordinates on large-scale military maps of the entire world. The UTM is the ellipsoidal transverse Mercator to which specific parameters, such as central meridians, have been applied.

The precursor to DIS, SIMNET, used the UTM coordinate system. However, DIS is intended to operate over larger geographic distances. As a result of this requirement, the geocentric coordinate system was chosen to be the earth-fixed-axis coordinate system. In order to establish the coordinate transformation between the DIS and SIMNET coordinate systems (geocentric and UTM), the geodetic coordinate was introduced. To define a geodetic coordinate system, the surface of the earth is approximated by a reference ellipsoid which is an ellipsoid of revolution defined by two parameters: the equatorial radius $a = 6{,}378{,}137$ meters (the semimajor axis of the ellipse) and the flattening $f = 1/298.257223563$. In DIS, the shape of the earth is specified using the World Geodetic System 1984 (WGS84).

Due to the dissimilar coordinate systems used by various vendors on their simulators, IST was tasked to provide an in-depth study of the existing publications on coordinate transformations and to provide a common set of algorithms to the I/ITSEC participants. A detailed study was made of previously published coordinate conversion algorithms, and a new set of parametric equations were derived for the study. Two issues considered in the study were the accuracy of the transformations and the real-time needs of a simulation exercise. In the case of a geocentric to geodetic conversion, IST developed a new algorithm to locate a point on the reference ellipsoid within 50cm or less. The algorithm proved to be the most accurate and the fastest in convergence. As a result of this study, a report titled "Interconversions Between Different Coordinate Systems" was published. See Reference [4] and Appendix B.

This report failed to discuss a conversion process between UTM and the other coordinate systems due to a misunderstanding about the nature of the coordinate system used in the SIMNET protocols. It was initially misunderstood that the SIMNET protocols were based on a topocentric system. This clarification necessitated a UTM to geodetic algorithm. Using the UTM to geodetic algorithm did not meet the requirement of a geocentric system as defined by the DIS standard. Another step was needed to transform the geodetic coordinates into geocentric coordinates. In short, in order to convert from

SIMNET to DIS, the SIMNET coordinates which are in UTM, need to be converted into geodetic coordinates and then converted into geocentric coordinates. As can be seen, converting one coordinate system into any other can be accomplished by one, or a combination of the other algorithms.

A set of equations was also derived to transform one set of orientation angles in a particular coordinate system into another. The orientation of a vehicle can be described using Euler angles, which consist of an ordered set of three successive rotation angles. The derivations focus on distributed interactive simulation applications, and the two simulation protocols referenced were the SIMNET and the DIS Protocols. One difference between the two protocols is in the representation of a vehicle's body axis. In the SIMNET protocols, a vehicle's body axis is defined using a right-handed Cartesian coordinate system; the body axis is defined with its x-axis pointing to the vehicle's right, its y-axis pointing to the vehicle's front, and its z-axis pointing up. In DIS, the coordinate system representing the vehicle's body axis is also defined with a right-handed Cartesian coordinate system. However, the positive direction of the x-axis extends out to the front, the y-axis extends to the right side, and the z-axis extends downward. The DIS convention is the more typical, being used in most engineering and physics courses. As a result of this study, a report titled "The Orientation Representation Between Topocentric and Geocentric Coordinate Systems" was published. See Reference [5] and Appendix C.

2.4 Terrain Representation

The delivery of the terrain data base was the responsibility of the P2851 team, a joint project designed to develop common data base 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 data base (GTDB) format and the SSDB interchange format (SIF). SSDB refers to the Standard Simulator Data Base which is the format P2851 uses internally. The SIF data format was selected for use by I/ITSEC participants.

The SIF data base used for I/ITSEC was selected to be a 100 x 100 km area which included portions of Fort Hunter Liggett, CA. The southwest corner of this data base was chosen to be (north 35 deg 15 min 0 secs, west 122 deg 4 min 0 secs). Terrain, culture, and models were to be prepared for this area. The source of the SIF data was initially unstated. The source was assumed to be Defense Mapping Agency DTED and DFAD. Many vendors questioned why they could not use their own DMA sources to obtain source data. It was finally revealed by P2851 personnel that the source of the SIF data was SIMNET, not DMA. The fact that SIMNET data was being used caused some initial problems among participants. These problems were eventually worked out to the satisfaction of the participants by clarifying that SIF data needs some source and that a good source was available from SIMNET.

Vendors had some initial problems using SIF data. The first problem was the lack of map products which they could use for data base development. Companies had to wait for delivery of the SIF data before their data base tasks could begin because the specific feature and terrain representations used by SIMNET were unknown unless a map or the data base were available.

The second problem related to offsets. Different parts of the data base were represented by offsets from a data base origin. It was not initially apparent that the SIF data had different offsets for terrain and culture which were not initially apparent.

The third problem was coordinate conversion methods. SIF uses geodetic coordinates for position definition, DIS uses geocentric coordinates, and SIMNET uses UTM coordinates. Conversion routines used to create SIF from SIMNET were not provided to all participants. When IST personnel inquired about the conversion routines, separate but similar versions were provided to IST by KOAN and BBN. The routines provided were portions of the S1000 system created for SIMNET.

Some participants did not foresee the need to have consistent methods for converting between these different coordinate systems. Project 2851 did not have such routines available for participants. IST developed standard conversion routines based on both the algorithms provided by BBN/KOAN and a literature survey and then provided them to all participants. See Reference [4], [5], and [6].

IST originally left SIF compliance testing to the Air Force or their contractor PRC. However, it was quickly realized that the Air Force and their contractor were primarily concerned with getting the data base ready. Therefore, matters related to data base correlation and P2851 compliance testing were not given high priority. There were two additional difficulties with SIF data which were not previously mentioned. The first problem dealt with the sheer quantity of data which made processing by PRC difficult. Data was to be delivered for the 100 x 100 km gaming area in both gridded and polygonal formats. The second problem dealt with corrections to the data base by P2851 personnel. Discontinuities in culture and terrain were discovered by PRC and revised data bases were prepared and distributed. In addition, enhancements were made to subsequent releases of the data base. Tight schedules made freezing the data base necessary.

Most of the discussion so far has referred to problems with the P2851 data base. It must be emphasized that P2851 is a new standard, as is the DIS standard. Project 2851 data does not have a large installed base of expertise or product; therefore, IST feels confident that as P2851 matures, the problems will diminish.

2.4.1 SIF Database

Because the Hunter Liggett database was converted from a SIMNET database into SIF, the "golden version of the data" was the 3-D polygonal representation. In SIF, terrain is represented as a uniform grid of elevation posts, like DMA DTED. In this particular case, the grid was made by sampling the SIMNET polygon elevations at a one arc second interval (approximately 30 meters between posts). In the sampling process data could be lost. Therefore, the original 3-D polygons were included in the SIF distribution, so participants could choose which data format to use.

A high resolution area of 10 kilometers N/S by 30 kilometers E/W was specified as the area containing all ground vehicle activity. Participants were advised to convert the high detail area as faithfully as possible. The error threshold requested of participants was set at 1.0 meters. The southwest corner of the high detail area was (N 35 deg 53 min 23.24 secs, W 121 deg 20 min 17.07 secs).

2.4.2 Models

During the first planning meeting, it was decided that existing SIMNET models would be used for each entity's polygonal representations shown on each simulator's visual system. If participants chose a vehicle not available in SIMNET, they would supply to P2851 a representation of the vehicle they chose for distribution to all other participants. IST offered to provide limited model format conversion assistance to participants bringing their own data. Because no data was received for any of the non-SIMNET vehicles requested, IST used the S1000 modeling system (developed under the SIMNET program) to create the needed models. The new models were constructed with design criteria (number of polygons, type of attributes, etc.) similar to existing SIMNET models. When completed, all models were delivered to KOAN Corporation in S1000 format. The models were converted to SIF by the same software used for the Hunter Liggett SIMNET database. As a SIMNET database, it was in S1000 format.

3. TESTING

The verification and validation of DIS compliant systems for the I/ITSEC demonstration was 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 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 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 every system passing the test plan. Desensitized test data and integration information is presented in a later section. By mutual agreement, each company's test results are confidential[5].

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[5] Review of actual test data must be approved by STRICOM.

3.1 Test Plan

The original concept in developing the test procedures (see Appendix D) for the I/ITSEC was to create a document that served the participants of I/ITSEC and would also be suitable for testing any simulator which purported to comply with the requirements of DIS. In particular, the test procedures were developed to evaluate the Entity State PDU, the Collision PDU, the Fire PDU, and the Detonation PDU. Additionally, simple tests were developed to ascertain whether compliance with one meter accuracy with SIF data was being met by I/ITSEC participants.

The following were some basic ground rules used in developing the test plan:

1) Intrusion into the simulator under test was forbidden. Any data to be gathered had to be gathered from the network;

2) Testing would follow a "bottom up" process. Testing would begin with bit alignment and ultimately move up to a level of consistent interpretation of a PDU;

3) A deductive testing strategy would be used instead of an inductive testing strategy. Deductive testing uses the analysis of definitive data to determine compliance with tests. Inductive testing uses a certain set of behavior to make judgements about other behavior; and

4) Testing needed to evaluate the system under ideal, adverse, and erroneous conditions.

First, intrusion into a simulator's internal operation was forbidden. Although IST had access to some of the internal operation of its simulators, such access could not be assured in other organization's simulators. This ground rule caused some problems with the test design.

Tests were designed to evaluate the extent of SUT performance without knowing the dynamic range of specific simulators. The result of this strategy was to require simulators to exhibit behavior which would not be typical in a normal simulation exercise. For example, procedures were developed which asked simulators to make a series of rotations to ensure consistent interpretation of Euler angles between the simulator coordinate system and the earth's Cartesian coordinate system. For many simulators, such a requirement caused maneuvers which could not occur in either the actual or simulated environment. Special test software would need to be generated by the SUT to demonstrate compliance with the test procedures. This special software was needed because internal algorithms were not available to analyze for system limitations.

Second, the testing process was bottoms up. The purpose of this strategy was to isolate basic syntax problems from semantics problems. This approach provided the most straightforward method of troubleshooting. IST felt that basic interpretation of PDU internal structures was necessary before interactive or interpretive tests could be conducted.

Third, deductive testing methods were used instead of inductive testing. In deductive testing, specific data is gathered and analyzed. Data gathered and analyzed is used to confirm the compliance with a directly related set of test criteria. The deductive approach is comprehensive and also lengthy. Inductive testing, on the other hand, uses data gathered for one set of criteria to confirm the acceptability of other criteria or an expanded set of criteria. Inductive testing is not as comprehensive as deductive testing, but it is faster. That is, incomplete deductive testing reduces to inductive testing. Likewise, complete inductive tests become deductive tests. Statistical methods are used to measure the confidence in inductive testing or the degree of uncertainty in deductive testing. The intent of the IST test strategy was to minimize the degree of uncertainty in deductive tests.

Finally, testing a SUT under ideal, adverse, and erroneous conditions was used. IST's goal was to create test procedures which stressed the simulator. In addition, one goal was to ensure that if the simulator failed, then the failure would not adversely affect other simulators on the network. Bad data must be rejected by a simulator without causing other problems to be generated. Therefore, testing methods sent data to determine compliance with DIS, the dynamic range of relevant simulator parameters, and the simulator's response to bad data.

A particular set of tests was developed to determine consistent terrain polygonalization between simulators. The I/ITSEC ground rules identified two criteria for matching P2851 source data. Within a special 10 x 30 km area, participants were asked to match SIF polygonal source to within one meter. The remainder of the 100 x 100 km gaming area could use polygon or gridded SIF, and matching was to be at best effort. Only in the 10 x 30 km high correlation area could interaction with the terrain occur. IST's test methods were designed to address the high detail area. The approach was to use IST's Computer Generated Forces internal representation to generate normal vectors on a particular set of polygons. These normal vectors could then be compared with normal vectors for a participant's simulator operating on, or parallel to, the particular polygon. Another method which would have vehicles follow a particular course and have observers view the SUT's behavior was rejected by I/ITSEC participants.

A second set of test procedures were developed. These tests were called the "Reduced Scope Tests." See Appendix E. These procedures were developed because I/ITSEC participants did not have sufficient time or budget to write test software required of the full test plan. In addition, IST had no enforcement rights to limit participation at I/ITSEC, especially when participants were making diligent attempts to make their

systems compliant with DIS 1.0. Therefore, a reduced set was developed for testing compliance with DIS 1.0. The testing for the I/ITSEC, therefore, became inductive versus deductive testing.

The reduced scope tests were less concerned with consistent interpretation of DIS semantics and more concerned with DIS syntax. Therefore, emphasis was placed on ensuring proper bit orientation in PDUs and appropriate responses to simple actions. For example, Fire PDUs should be followed by Detonation PDUs if the rounds impact items. Air participants also requested exemption from processing collision PDUs. The reason, IST believes, is due to excessive computing necessary to process collisions and the variety of ways available to process collisions.

IST believes the reduced scope tests resulted in an increase in anomalies because of the inductive test techniques. However, the majority of anomalies were masked by creating the proper scenarios. Initially, IST determined that no anomalies would be permitted. This position was changed to allow the participants the opportunity to decide whether anomalies, or test plan exceptions, would be permitted. Finally, IST received approval from participants during the final testing rehearsal period to act as their proxy in deciding whether specific anomalies would preclude network connection by a participant.

3.1.1 Interoperability Tests

This section briefly describes the interoperability tests contained in the reduced scope test plan. Each test is described within the context of the test's purpose. See Appendix E for more details on each test.

3.1.1.1 Network Tests

Specifying the appropriate addressing structures and data length fields was a prerequisite to being able to exchange DIS PDUs. Network tests verified a player could generate and interpret these addresses and the data lengths for the UDP/IP/Ethernet communication protocols. Because the purpose of the network tests was not to test conformance of the SUTs implementation of the UDP/IP/Ethernet protocols, only those fields which are important to the transfer of DIS PDUs, namely addressing and data, were checked. Data integrity calculations, for example, checksums, were not checked other than to determine if the transmitted data had been corrupted. If the data had been corrupted, it was discarded. SUTs that were not transmitting data (i.e., Stealth and/or radar displays) were required to receive the data only. All other SUTs were required to pass all network tests described in the test plan.

3.1.1.1.1 Broadcast

To test broadcast transmission, the SUT built and sent one or more UDP/IP/Ethernet packet(s). The data content for the packet(s) had to be the type of data produced during the demonstration. The packet was captured and verified with respect to the correctness of the SUT's UDP, IP, and Ethernet header frames for the following fields: destination address, protocol address, data length, and data content.

3.1.1.1.2 Point-to-Point

In the case where the SUT intended to use the I/ITSEC interoperability network for non-DIS traffic, it was required that the information be sent using a unicast, or point-to-point, service. In this case, the SUT had to demonstrate its ability to use this network service in order to be interoperable for the I/ITSEC demonstration.

Because it was likely that point-to-point traffic would be used by other demonstration participant, the SUTs had to expect such data and be able to receive and subsequently reject it without adverse affect on the SUT or the network. The SUTs that were using point-to-point services (those sending non-DIS traffic) on the I/ITSEC demonstration network were required to pass all tests described in the test plan.

3.1.1.1.3 ARP

In addition to the capability to send and receive information, it was recommended that the SUT be able to implement ARP in order to obtain or distribute physical address (i.e., Ethernet) information. This Ethernet address was used to establish point-to-point communications with the IST test system.

3.1.1.2 PDU Tests

Because the I/ITSEC demonstration served as a confirmation of the DIS protocol, tests for correct use of DIS were a major focus of interoperability testing. The DIS PDUs contained the simulation information that was exchanged during the I/ITSEC demonstration. It was critical that every SUT sending DIS data was able to correctly build and interpret DIS PDUs.

Tests described in this section of the test plan were used to determine whether the SUT could correctly build and interpret the application level data structures defined by the DIS 1.0 standard. Four PDU types were required for the demonstration: Entity State, Fire, Detonation, and Collision.

3.1.1.3 Terrain Orientation Tests

Another very critical component of interoperability was to achieve a common interpretation of the terrain. This included correct x, y, z representation of locations on or above the ground.

The required degree of correlation was dependent upon the type of entity. Entities that interact closely with the ground must demonstrate a high degree of correlation, whereas entities which do not interact with the ground (aircraft) require less correlation. Correlation was necessary for successful interoperability because each participant separately converted the terrain database supplied by P2851.

3.1.1.4 Appearance Tests

Tests in this section were intended to validate the algorithms used by the SUT to determine and interpret location, attitude, and velocity information, position of articulated parts, and special appearance indications.

The SUT performed a sequence of maneuvers described in the test plan which produced the types of PDUs to be tested. The SUT was tested to determine if it was calculating the correct values for inclusion in the PDUs. This included tests of location and orientation generation and interpretation. In addition, the SUT was tested to determine if PDUs were issued at times specified by the DIS standard. This was determined, in part, by correct dead reckoning routines.

3.1.1.4.1 Location and Attitude Tests

Tests were made to determine proper interpretation of location and orientation structures used in Entity State PDUs. Only the Entity State PDU was used for this section of tests. The protocol version, exercise identifier, padding, entity ID, force ID, entity type, and alternate entity type fields were not evaluated on this set of tests; therefore, their values were not relevant.

3.1.1.4.2 Dead Reckoning Validation

This test verified the consistency between a simulator's representation of linear velocity, orientation, and other dead reckoning parameters.

3.1.1.4.3 Appearance Validation

This set of tests verified the proper use of entity type and articulation parameters fields in the Entity State PDU. For the entity type validation test, the SUT had to be able to produce an Entity State PDU for each entity type it can generate. The SUT must also

be able to receive an Entity State PDU for each of the entity types listed in the IST "Entity Type Sheet" of 4 June 1992. See Table 3. The articulated parts validation test verified the correct use of the articulated parameters field.

3.1.1.5 Interactivity Tests

These tests verified that the SUT interacted appropriately with the rest of the simulation by generating events appropriately or by responding properly to externally generated events.

3.1.1.5.1 Maneuver, Shoot, Kill

This test verified that a SUT interacted with another simulated entity in a firing scenario. Data was checked to verify that the Entity State, Fire, and Detonation PDUs were produced in the appropriate order.

3.1.1.5.2 Collisions

This test verified that when a collision occurred, the SUT produced a valid Collision PDU and responded in an acceptable manner.

3.2 Test Tools

Software tools from several projects developed at IST were used to facilitate testing before and during I/ITSEC. These tools were outgrowths of projects related to Computer Generated Forces in the SIMNET environment. This section describes these and other tools which were developed specifically for testing. The test tools (except those described in Section 3.2.5) are contained on a disk in Appendix F.

3.2.1 IST's CGF Testbed

The CGF Testbed is a hardware/software node of a DIS network. The purpose of the system is to provide a number of entities in a DIS battlefield without the cost or manpower requirements of manned vehicle simulators. It consists of two components, the Simulator and Operator Interface. The Simulator performs vehicle dynamics calculations, remote entity approximation, behavior generation and control, and all other processing needed to represent CGF entities in the simulation. The Operator Interface provides a user-friendly mouse-and-menu interface which a non-technical operator can use to issue commands to CGF entities on the simulator.

The CGF Testbed was developed by IST as a research tool for Computer Generated Forces under the DARPA sponsored project

> **Intelligent Simulated Forces: Exploration of Computational and Hardware Strategies, contract N61339-89-C-0044,**

and the STRICOM sponsored follow-on project

> **Intelligent Autonomous Behavior by Semi-Automated Forces in Distributed Interactive Simulation, contract N61339-92-C-0045.**

As a research tool it has a number of built-in debugging aids and has been designed to accommodate a wide variety of entity and behavior types.

The simulator is briefly described in the following sections. More detail on its design and use is available in the Release document provided with IST CGF software releases and in IST's technical reports. The latest released version of the source code, instructions for installation and use, and the Release document are distributed for STRICOM by LORAL under the ADST contract. The files are available on the BBS operated by LORAL. The contact point for access to the BBS is Ms. Sheila O'Brien, (407) 382-4586.

The IST technical reports describing the CGF system can be found in Reference [8] through [14].

3.2.1.1 Simulator

The CGF system runs on PC/AT hardware. A minimal system uses one PC as a simulator to generate up to 12 entities. A simulator may be configured to operate under SIMNET or DIS protocols.

A PC running the CGF simulator software simulates the mental and physical behavior of its entities (weapons platforms and/or individuals in a battlefield environment) and generates network messages (PDUs) at the appropriate times and rates to allow other DIS entities to accurately interpret and depict their behavior in real time.

A simulator node normally operates as a subordinate unit to an operator interface node or to some other higher level control node; however, a debugging interface is built into the simulator code which allows direct control of the entities simulated on that (or even other) node.

A simple graphical display is provided which shows a plan view of the battlefield's terrain. Terrain features such as roads, rivers, trees, tree lines, tree canopies, buildings, etc. may be displayed. Vehicles are drawn showing heading and turret azimuth.

Depending on the configuration, the PC's display screen may have several different appearances. If the graphics option is enabled, the display depicts a map with two blue cross hairs dividing the screen horizontally and vertically, and two horizontal and two vertical lines spaced a terrain patch distance (500 meters as of this writing) north, south, east, and west of the cross hairs.

The cross hair intersection is the display (x,y) offset from the origin of the data base. The top of the display is north, left is west, bottom is south, and right is east. The origin of the data base is at the southwest corner. The display also outlines the edge of the terrain data base with cyan lines, which can only be seen if the display is near the edge of the data base.

The display (x,y) offset and scale are displayed in text in the lower right-hand corner of the screen. All of the display drawing is relative to the display offset and scale, where a scale of 1 is equivalent to 1 meter per pixel.

No terrain is displayed unless a locally generated entity is visible on the display. Terrain polygons can be displayed using the display command "d p".

A CGF Testbed simulator can be controlled via its keyboard by issuing text commands. The simulator's debugging interface allows an operator to command the system to add or remove simulated entities, to send commands to these entities, and to change various characteristics of the simulator dynamically. One important feature is its capability to read commands from a text script file instead of from the keyboard.

All commands begin with the commanded component's ID. The simulated entities have numeric IDs and the other components have character IDs. There are two modes for entity ID's. Global mode requires all commands to be preceded by the site and host values; local mode omits site and host values.

Command scripts provide a method for automating keyboard input of simulator text commands. Script commands begin with a delay time and are otherwise identical to the text command. Additionally, script processing directives can modify the rate at which characters of the text command are processed. Scripts can invoke other scripts using the load script command "k s scriptFile"; however, the new script replaces the original. This command should only be used as the last command in a script.

Scripts are useful when a series of actions can be predicted ahead of time and when repeatability is important. Scripts can be chained but cannot be nested or called recursively.

3.2.1.1.1 Usage in Testing

During testing, a personal computer running the CGF Simulator was moved to the participant's work area where it was connected to a system under test (SUT) via the network. The CGF Simulator's graphical display was used to observe the entities generated by the SUT. For testing of Dead Reckoning and vehicle dynamics calculations a visual inspection of the icon representing an entity generated by the SUT gave a good indication whether or not its movement in the XY plane correlated with heading and XY velocity. Turret azimuth was depicted.

Entity type could be determined through the "m e" debugging commands which displayed a list of all entities being tracked by the CGF system as well as critical information for each.

The CGF simulator was used to generate entities which were made to interact with the SUTs' simulators or simulated entities. IST's CGF entities collided with, shot at, were shot by, observed or were observed by the SUTs'.

3.2.1.1.2 Limitations

The CGF Simulator has a number of limitations which determine the kinds of tests that can be performed with it. Some of these are listed below and their effects on I/ITSEC testing are described.

1. Remote Entity Approximation Limits

   The number of entities that a CGF system can track, while also simulating entities, varies with the speed of the hardware used to host the CGF simulator. The CGF system running on a 486/50 PC could generate three entities while listening to the peak loads of 50-60 entities generated during network free play periods.

   Initial measurements at IST indicate that such a CGF system may be able to generate 12 entities when there are no more than about 20-30 external entities active.

   For this reason, IST was not able to stress some of the participants whose systems could track hundreds of external entities.

2. Local Entity Limits

   The CGF system has hardcoded limits (12 because of memory required for terrain regions) on the number of entities that a simulator can generate.

3. User Unfriendly

The keyboard interface to the simulator is hard to use. Commands are cryptic and many must be memorized. Some commands must be entered quickly and the "fat finger" syndrome can cause disastrous results.

4. Graphics Display

The display has a limited field of view and represents only two dimensions. The display gives no indication of roll, pitch, Z-location, Z-velocity, or gun elevation. The "m e" commands (described later) provide a numerical display of the Euler angles, but these are not very useful for observation of changing values.

3.2.1.1.3 Mods for DIS

The CGF system was originally developed solely as a SIMNET node. When it was determined that it should support DIS, a significant software redesign was begun.

In the original system, the SIMNET protocols were not separated from the application. SIMNET data structures appeared in the lowest levels of behavioral generation (sometimes requiring byte swapping for use within the behavior code) and the state transitions required by the communications protocols were merged with the entity behavior. Conversion to DIS provided a wonderful opportunity to re-design in such a way as to separate the network protocol software from the rest of the system.

At first it appeared that a translation layer might be appended to the CGF system. Development of functions to convert from SIMNET data structures to DIS data structures was started using a preliminary code from TSI. This code was about 20% complete. All the conversion routines required to go back and forth between SIMNET PDUs, and DIS were developed. At this time the topocentric coordinate system was mistakenly selected for SIMNET (it uses UTM).

It soon became evident that a more significant rearrangement was required in which the communications protocols would be separated from the application. The SIMNET protocol stack consists of a SIMNET (application layer), a SIMNET Association Protocol (AP), and IEEE-802.3. Each of these layers can be replaced with one layer from the appropriate I/ITSEC protocol stack. DIS can replace SIMNET, UDP/IP can replace AP, and IEEE 802.3 can repiace Ethernet.

Separation began with a definition of Service Access points (SAPs) for the SIMNET application protocol, Association Protocol, and IEEE/802.3 protocols. The code was rearranged to reflect this layering. Before this separation, all the protocol layer headers were lumped together.

Development of the UDP, IP, and Ethernet protocol layers followed. UDP and IP were developed at IST from the RFCs 768, 894, and from Reference [13] because IST wished to retain the direct control over the handling of interrupts from the communications hardware (3COM Etherlink-II) used in our system. Commercially available software providing UDP/IP facilities with the hooks required by the CGF system was not available.

Service access points in the corresponding new layers were written with identical signatures (names and parameters) so that choices could be made at each layer and only the desired modules could be linked. Thus the simulator could be configured to use any of the eight combinations of the following protocols, although only two of the eight are likely to be used. These are:

Application	**Network**	**LAN**
SIMNET	ASSOCIATION	IEEE 802.3 (Standard SIMNET)
SIMNET	UDP/IP	IEEE 802.3
SIMNET	ASSOCIATION	ETHERNET2.0
SIMNET	UDP/IP	ETHERNET2.0
DIS	ASSOCIATION	IEEE 802.3
DIS	UDP/IP	IEEE 802.3
DIS	ASSOCIATION	ETHERNET2.0
DIS	UDP/IP	ETHERNET2.0 (I/ITSEC 1992)

Integration into the reorganized testbed was greatly simplified by the separation of the protocol layers. A set of internal data structures was selected, primarily derived from data types used by the SIMNET Appearance, Fire, and Impact PDUs. While some of the testbed data structures are clearly derived from SIMNET roots, the testbed application is truly independent of the SIMNET protocol.

As an example of how all this works, consider an appearance change taking place to a vehicle controlled by the testbed. The testbed calls a service access point (SAP) to use the application layer simulation protocol. Whether the loaded application protocol is SIMNET or DIS, the SAP is the same, in this example "SendAppr." If the SIMNET application layer module is linked in, a SIMNET APPEARANCE PDU would be built and sent to the network layer. If DIS is linked in, an ENTITY STATE PDU would be built and sent to the network layer.

The network layer alternatives were UDP/IP or AP. In both cases, the interface to the service to send a single broadcast appearance message is the same (SendNet). The application level does not need to know what layer is being used below it, similarly for the interface between the NETWORK layer and the LAN levels. Because IST only supports one hardware interface, the 3COM Etherlink-II, there is no choice at the board layer, but there could be.

UDP/IP was selected by the I/ITSEC participants on 10 April. By 24 April, IST had investigated the protocol and had prototype code reading and writing UDP/IP. This was tested against commercially available UDP/IP packages on several machines to gain confidence in the understanding of UDP and IP, as well as ARP.

Approximately two months was required to complete, test, and debug the new UDP, IP, and IEEE/802.3 modules. Work continued on the DIS layer up through the I/ITSEC practice week as a further understanding of the standard was gained. In development of the DIS applications layer, it was discovered that a great deal of familiarity was still required with the CGF system's implementation of vehicle dynamics, SIMNET data structures, and the arrangement of the protocol interfaces.

Several modifications to the application were required to support DIS because some data required to build or interpret DIS PDUs was not present in the CGF system (it is not required by SIMNET).

1. Collision processing was developed to operate under SIMNET and this was then converted for DIS. Improved collision detection was developed.

2. Articulated parts needed more data than SIMNET version provided. The current value of each part's change flag had to be saved so the next sequential number could be used for each change.

3. Numbering of DIS entity IDs starts at one. The application layer was modified to increment internal IDs by one to output as DIS and to decrement incoming DIS IDs by one. A complete repair involved an internal data switch and was too complex to implement at this time.

4. DIS Fire PDUs required a velocity value to be sent to the applications level SAP.

5. Engine speed is not represented in DIS. Although it was not done in the CGF testbed, a function could be provided to make assumptions about engine speed based on other known parameters such as velocity and entity type.

6. DIS 1.0 has no specific "deactivate" or "remove entity" PDU. Therefore "tricks" had to be developed to ensure that viewing simulators would not continue to project the paths of exploded missiles after their impacts. One "trick" had missiles produce one last Entity State PDU, placing them at the center of the earth with zero velocity.

7. A way to generate unique event IDs was required.

Some elements of DIS/SIMNET conversion required significant effort. Coordinate conversion between SIMNET's UTM based flat-earth system and DIS's geocentric,

elliptical earth system was quite involved. Once it was realized that SIMNET had been using the UTM coordinate system instead of a topocentric one, new algorithms, derived from Reference [4] and [5] were adapted. These were subsequently distributed to all and were used by most San Antonio participants.

Conversion between SIMNET object types and DIS entity types was implemented using extensive lookup tables. It should be noted that Appendix H2 of the DIS Standard (see Reference [1]) defines a number of entities in what appears to be a rather haphazard order, especially for surface ships, whose classes should have been reordered to keep hull numbers monotonously increasing.

Articulated parts in DIS required records to be kept identifying the last modification of each part.

One of the nastiest conversions was between SIMNET and DIS appearance descriptors. The arbitrary and confusing allocation of bitfields in DIS turned what could have been a very simple mapping into an involved process that required hundreds of lines of code and required knowledge of the DIS entity type for the conversion.

Ambiguities and vague definitions in the DIS standard led to varying interpretations of some fields. These were detected at San Antonio and were resolved there, some by voting. One example was the DIS definition of impact types.

The first release (Version 2.0) of IST's DIS CGF was made at the participants' meeting on 27 August 1992.

3.2.1.1.4 Mods for Testing

Before I/ITSEC, it was discovered that the CGF Testbed was difficult to use or lacked some capabilities which would be required if it was to be used extensively in testing.

1. Some kinds of information were needed which were not currently displayed, for example, IDs, types, locations, and appearances of "all local entities," "all remote entities," or "all entities."

   IST Added the "m e" commands which list:

ID	(site, host, entity number)
type	(e.g. "T72" "A10", etc.)
location	(X, Y, Z)
speed (mps)	
attitude	(roll, pitch, yaw or heading)

The command may specify all entities, all local, or all remote.

Command:	m e [a r l]
Meaning:	Display entity information for all entities, all remote entities, or all local entities.
Example:	m e a

2. It was impossible to keep a fast moving entity visible on the debugging PVD, so commands were designed to instruct the display to periodically center itself on the current location of an entity whose ID was specified:

Command:	d c id period
Meaning:	Center display on entity id# once every time period
Example:	d c 5 100.

If a period of 0 seconds is specified, the action is performed only once.

3. In order to test participants' detonation detection and damage evaluation routines, a method was needed to make it easy to shoot them. IST developed a "debug" command to generate a detonation PDU with any I/ITSEC munition type aimed at any entity without checking the firing platform's capability. This enabled us to destroy any I/ITSEC platform with any of our vehicles.

4. Because of the (foreseen) problem with mis-correlation of terrain databases, IST added a new debugging command to apply a position offset to an entity's position just before coordinate transformation and broadcast.

The command was:

] 24 <x_offset> <y_offset> <z_offset>

All routing, movement, line-of-sight (LOS), and so on use current positions as usual. The offset is added to outgoing Entity State PDUs for all entities (including missiles) just before coordinate transformation and output. The idea is that the offset can be used to make crude adjustments to compensate for Terrain Data Base (TDB) mismatch, so as to make Simulator entities appear to be located on the terrain polygon. This offset works best for motionless entities; IST's participation in the plenary and banquet demonstrations called for only motionless entities.

5. A number of entity types were added for I/ITSEC. IST attempted to add all I/ITSEC entities to the list of all SIMNET entities. A few new DIS and SIMNET entity types had to be created to avoid ambiguity.

6. Simple ship dynamics were added.

3.2.1.2 Operator Interface

The operator interface provides a convenient mechanism for the operator of a CGF in a training exercise. It was not used for testing in San Antonio or prior because it required another PC and the Operator interface does not provide many of the low-level detailed capabilities needed for system testing.

The CGF Operator Interface is not described in this document. Details on its use is available in Reference [13].

3.2.2 IST's PC-Based Data Logger

The logger and its associated utilities are briefly described in this document. More detail on use is available in the documentation provided with IST CGF software releases.

3.2.2.1 Data Recording

The IST Data Logger is a PC based tool developed along with the CGF testbed. It runs on the same hardware but like the simulator, must run stand alone.

The logger captures Ethernet packets from the network and writes them to a disk file with a timestamp. Packets can be written unchanged in their binary form so they can be replayed at a later time (with the "playback" tool). Also, they can be interpreted and an ASCII display of their various fields can be written as a "text" file to be printed or examined with a text editor. It is possible to generate both kinds of files simultaneously.

To interpret packets, the protocol layers are examined in order to determine the next embedded protocol. If an unknown protocol is encountered, the packet contents will be written in a hexadecimal dump format.

Several options can be toggled on or off while the logger is running:

> A screen indication noting the type of each received PDU can be enabled or disabled. Screen output is limited to the number of the packet in the order received, the mnemonic name of the simulator sending the packet (Ethernet address is used if no mnemonic name is known), and the type of PDU within the packet. More information can be displayed, but too much screen output can result in lost packets.

Writing to a binary file can be started or terminated. Restarting reopens and overwrites any previous binary file.

Writing to a text file can be started or terminated. Restarting reopens and overwrites any previous text file.

A graphical network monitor display can be turned on or off.

The logger is primarily designed to capture network packets and log them in a binary file which can be manipulated using FILTER.EXE and PLAYBACK.EXE to produce text files to help with debugging, or to replay logged exercises. The capability to log text has been included, but should not be used to log large exercises because the amount of work being done to interpret and write the packets can result in some information being lost. Also, the size of the files produced this way may be quite large.

By default, the PDU text file is "PDU.TXT" and the PDU binary is "PDU.BIN". If there are command line arguments, they are used to override the default. The first argument names the text file and the second argument names the binary file. Thus, to specify a binary output file, a text output file name must also be given, even though it may not be used. Path names may be included in the file name to direct the output to a different directory.

Example usage:

LOGGER TEXT.TXT BINARY.BIN

An Ethernet address file is required to map the Ethernet address to symbolic names. The file is named ADDRESS.DAT and the logger will not run without it, although it may be empty, resulting in Hex addresses on screen and in text files.

Due to the frequency of BBN SIMNET Stealth Appearance PDUs, they are not logged to text output files at this time. A minor change to the logger code would allow text logging of Stealth appearance PDUs, if desired.

The logger defaults to screen output with no file output. The options mentioned above are each independent of the other and can be toggled on and off with keyboard strokes.

3.2.2.1.1 Usage in Testing

The data recording facility was used during testing to capture a SUT's network traffic for immediate analysis. Text files were most often used. Examination of text files allowed rapid determination of such items as correlation of event IDs between Fire and Detonation PDUs, Entity types, appearance bits, protocol header field values, etc. This was probably the most productive debugging and analysis tool.

3.2.2.1.2 Limitations

The logger was designed to record every network packet indiscriminately. This resulted in large files at times but a more troubling problem was loss of data. With all screen output disabled and all logging disabled, the logger could handle approximately 1000 interrupts (packet received and discarded) per second. Binary logging reduced the rate to about 120 Entity State PDUs per second. Text logging further reduced this by a factor of at least 10.

3.2.2.1.3 Mods for DIS

Converting to DIS required significant modifications to the logger. In order to generate ASCII text displays of PDUs, each protocol layer had to be parsed dynamically. At the application level, a large amount of code was devoted to the display of the different data types in the various fields.

Some of the work required to analyze the UDP and IP layers had already been done in the CGF testbed conversion.

3.2.2.1.4 Mods for Testing

No modifications were made to the Data Logger specifically for testing for I/ITSEC.

3.2.2.2 Data Playback

The "playback" utility provides retransmission of packets from a logged binary file. The retransmission can be to the screen, a text output file, or the network. The file name may include a path indicating where the input file is located. The starting and stopping times can be selected from the command line. A scale factor can also be provided for replaying an exercise at a different speed from which it was originally logged.

3.2.2.2.1 Usage in Testing

Playback was not of significant value in the I/ITSEC testing.

3.2.2.3 Data Filtering

The "filter" utility removes unwanted PDUs from a binary PDU output file.

Usage: FILTER [options] infilename outfilename [+|-] pdukind [pdukind [...]]

The '+' operator will place only PDUs with the given kind(s) in the output file. For example,

    FILTER foo.out bam.out + 2 3 4

will place all PDUs of kinds 2, 3, and 4, from the file foo.out case into the file bam.out.

The '-' operator will place all PDUs except those with the given kind(s) in the output file.

The PDU kind numbers have an offset associated with them to avoid number conflicts. This offset must be added to the PDU kind number when running the filter program. Offsets for PDU types are:

SIMNET SimulationPDUs	0
dis_SimulationPDUs	100
SIMNET StealthPDUs	200
IST Messages	300

Options supported are:

- -v Always keep only the first Vehicle Appearance PDU from each vehicle.
- -e Always keep only the first DIS Entity State PDU from each vehicle.
- -t Use text input and output instead of binary.

3.2.2.3.1 Usage in Testing

Filtering was used during testing when the data rates were high enough that direct text file logging was impractical. Then binary files were generated and filtered output was used to generate binary or text files for examination via text editor.

3.2.2.4 Network Monitor

A graphical display of the network activity can be invoked using the logger. A stylized display shows company logos and the counts of various types of PDUs per company or per node. The counts may be reset manually.

3.2.2.4.1 Usage in Testing

The network monitor was not used during testing of individual company simulators. It was set up on the display floor during I/ITSEC where it provided a display for interested onlookers and was of some use in testing the network for connectivity.

3.2.3 Protocol Analyzers

3.2.3.1 UTST

The UDP TeST program (UTST) was developed for internal use at IST during IST's UDP development. With the approach of I/ITSEC, it was realized UTST could be used to validate other I/ITSEC participants and to assist other participants in their UDP development. It was first made available outside of IST on 29 September 1992. Modifications continued through approximately 20 October 1992.

UTST is capable of parsing incoming packets at various layers and of transmitting ARP and other UDP/IP traffic. It consists of two parts: an executable (utst.exe) and a configuration file (config.u).

UTST is run on a PC compatible computer with a 3COM board (such as the machines used to run the IST simulator). It monitors the LAN and displays LAN packets. Its purpose is to parse and display UDP packets in a human readable fashion (along with the first bytes of data). Non-UDP packets are parsed as far as possible in the UDP/IP/Ethernet stack; for example, a TCP packet will have its Ethernet and IP information displayed, but the TCP header is just treated as part of the data.

UTST recognizes and displays ARP and Internet Control Message Protocol (ICMP) packets. It automatically responds to ARP requests when appropriate. UTST will transmit ARP requests and short text messages on request.

The remaining paragraphs detail the use of UTST.

3.2.3.1.1 The UTST Windows

There are three windows making up the UTST display.

Topmost, with a cyan background, is the status window. The first line of the status window shows the Ethernet and IP addresses for the machine on which the program runs and also indicates when UTST is filtering packets. When UTST filters packets, only packets directed to the host on which it runs (point-to-point or broadcast) are displayed. When filtering is off all packets are shown. The second line shows the target IP address, the Ethernet address (zero until an ARP is sent), whether UTST is pausing after each packet (Pause ON) or showing packets in real time (Pause OFF), and the target UDP port.

The initial settings for the local IP address, target IP address, target UDP port, filtering, and pause are determined by the configuration file (config.u). The local Ethernet address is determined by querying the 3COM board. The remote Ethernet address is determined through ARP requests.

The second UTST window (blue background) is the send window. Except as noted below, user keystrokes are buffered internally and echoed in this window. When the user presses ENTER, the message shown in the bottom line of this window is sent as null terminated data in a UDP packet. If the target Ethernet address is unknown (displayed as all zeros), ENTER will generate an error report in this window.

The third UTST window (gray background) is the receive window. The receive window is used to display incoming packets. All packet displays begin with a dark gray double-line. Except for ICMP messages, the next lines display Ethernet information. If the packet is an IP packet, the IP header information follows. If the IP packet contains a UDP packet, the UDP data is shown next. At the first point where the header is not recognized (or after the UDP header), up to 64 bytes of data are shown.

ICMP packets are displayed somewhat differently in order to present more useful information. When an ARP reply is transmitted this is noted in the receive window.

3.2.3.1.2 The UTST Configuration File

Except for the arrow keys, all UTST commands use ALT keys combination. Most of the commands involve changes to values which may be read from the configuration file.

ALT-X	Exit the UTST program.
ALT-H	Prints a command summary and the UTST version number.
ALT-A	Transmits an ARP. The ARP's target is the target IP address shown in the status window.
ALT-E	Transmits an ICMP echo request to the target IP address.
ALT-T	Enter a new target IP address. This invalidates the Ethernet address.
ALT-L	Enter a new local IP address.
ALT-U	Enter a new UDP Port ID (used for transmission).
ALT-F	Toggle packet filter.
ALT-P	Toggle start-of-new-packet pause.
ALT-N	Continue from pause at new packet start (pause is indicated by "Pause : WAIT" on the second line of the status window).
ALT-C	Clear the receive screen.
Arrows	Up and down arrows increment and decrement the last part of the target IP address. The left and right arrows decrement and increment the UDP Port ID used for transmission. The arrows are sometimes faster than using ALT-T/ALT-U.

3.2.3.1.3 The UTST Configuration File

A configuration file is not required but is a convenient way to set up defaults.

Lines starting with an asterisk, or which are completely blank, are ignored. A configuration line is only examined as far as necessary to retrieve settings, so most configuration options can be followed, on the same line, with remarks. The configuration file is read case blind.

The configuration option lines begin with an option name, the option name is followed by white space, and then the option value is supplied. The configuration options are:

iplocal

Specifies the IP address of the host on which UTST is running. "iplocal 132.170.191.146" is a valid specification.

iptarget

Similar to iplocal but specifies a target address. ARPs and messages will be sent to the address specified.

port

Specifies the UDP Port ID to be used for outgoing messages. "udp 3000" specifies that messages should be directed to UDP Port ID 3000.

filter

Values of "on" or "off" are accepted. Determines whether UTST will ignore packets not targeted to this host (on) or not (off).

pause

Values of "on" or "off" are accepted. Determines whether UTST will pause before displaying a new packet (on) or not (off).

3.2.3.1.4 Usage in Testing

For systems that seemed otherwise healthy, UTST was used to generate ARP requests to SUTs. UTST made it easy to recognize ARP responses. Sometimes UTST was used to generate point-to-point traffic to ensure the SUTs were unaffected by such traffic.

Beyond testing, UTST was used to analyze errors in systems under test with the goal of assisting the potential participants to meeting participation requirements. For example, two potential participants' vehicles were not visible on the IST testbed. The testbed indicated the layer at which the SUT's packets were being discarded, but the testbed was not designed to give a complete analysis of problems with arriving packets. Furthermore, packets discarded by the testbed are not necessarily in error. They may be point-to-point to another station. For these participants, the logger gave no further information.

Using UTST, a complete analysis of packets could be done. For example, for two SUTs it was discovered the SUTs were not correctly computing UDP checksums. With this

insight it was possible for those two participants to rectify serious problems with their simulators.

3.2.3.1.5 Limitations

UTST is only suitable for examination of details of the UDP/IP packets and for testing ARP transmissions. It does not parse application layer packets. UTST is designed to analyze interactions between itself and a system under test. It can be used as an intelligent line analyzer to a limited extent, but as traffic increases this becomes infeasible.

3.2.3.2 ATST

The Arp TeST program (ATST) was developed for internal use at IST during IST's UDP development. Soon after development of the first version of ATST its usefulness as an I/ITSEC tool was apparent. The first versions of ATST were created in late September, 1992. It was last modified on 16 October 1992. It was not modified at the I/ITSEC site.

ATST transmits ARP requests to a list of IP addresses and notes ARP replies. It consists of two parts: an executable (atst.exe) and a configuration file (config.a).

ATST is run on a PC compatible computer with a 3COM board (such as the machines used to run the IST simulator). It continuously transmits ARPs to a user specified list of IP addresses and indicates those addresses from which it receives a reply. The intent is to automatically build a list of sites that are on a LAN.

The remaining paragraphs in this section detail the use of ATST.

3.2.3.2.1 ATST Use

The file config.a is read by ATST when it starts. Each line of the configuration file consists of an IP address followed by a participant name, for example:

132.179.103.146 IST

When ATST runs, the list of address/name pairs is displayed (yellow on aqua). Each one in turn is:

- highlighted (made white),
- an ARP is sent to the indicated address,
- ATST pauses, and
- the line is returned to its former color.

When the list is exhausted, the process begins again with the first address. When an ARP reply comes the corresponding line changes to black. Replies can come in any order at any time, it is not necessary for the reply to arrive during the built in pause.

At a glance, a user can tell which participants have replied. The user has a few options available:

ALT-R refreshes the screen. Those participants who have responded are re-drawn in red, so after a refresh the user can tell who has never responded (yellow), who responded at some time since ATST started (red), and who has responded since the last refresh (black);

Up arrow: increases polling speed (decreases the delay between ARPs);

Down arrow: decreases the polling speed (increases the delay between ARPs); and

ALT-X: Exit ATST.

3.2.3.2.2 Usage in Testing

ATST was configured to ARP all the participant addresses. In a matter of seconds ATST generated a list of who was on line (measured by responsiveness to ARPs).

3.2.3.2.3 Limitations

ATST will only support 75 addresses, but that was more than enough at I/ITSEC. When asked to operate at full speed, ATST generates significant traffic (hundreds of PDUs a second) which sometimes interfered with other tests. ATST only reports positive responses (i.e., if a participant responds it is so marked, if it responds to the next ARP no indication of this is given, although ALT-R is used to fill this role to a degree).

3.2.4 DIS Conversion Utilities

Some test tools were developed to facilitate the test procedures involving coordinate and timing conversions. Due to the number of heterogeneous simulators involved at I/ITSEC, conversion utilities were developed to automate the testing process. Test data was easily analyzed with little time and effort using these conversion utilities. Also, these utilities provided accurate and consistent results to allow the other simulators to debug their coordinate and timing representations. These tools were developed on a 486-PC using the C language and are easily portable to a Unix based platform.

3.2.4.1 Coordinate Conversion Utility

As mentioned earlier in this report, there are a number of coordinate systems a simulator may choose to represent its position and orientation. However, the most common coordinate systems are geocentric, geodetic, topocentric and Universal Transverse Mercator (UTM). The test tools provide an easy way to transform a set of coordinates from one axis into another.

There are three test tools which perform coordinate conversion. The first utility allows positional data to be converted between the four coordinate systems. For example, given a set of (x,y,z) in topocentric, one may obtain positional representation in either geocentric, geodetic, and UTM. The second utility performs conversions for velocity vectors, and the third utility performs Euler angles conversions.

3.2.4.1.1 Usage in Testing

These utility programs are written to allow the user to input a set of values in one system with minimal understanding of the program. The program will accept inputs in one coordinate system and convert and display the values in the other coordinate systems. The input coordinates must be designated as:

1) "to 50000.0 50000.0 10000.0" representing topocentric (x,y, z), or

2) "gc -2655903.39 -4428424.57 3748862.60" representing geocentric (X,Y, Z), or

3) "gd N 36.0 9.0 43.66 W 120.0 57.0 10.09 10391.75" representing geodetic latitude, longitude and altitude above mean sea level, or

4) "ut 684996.68 4003199.53 10000.0" representing UTM easting, northing and height.

The other three output forms are calculated by the program. The other conversion utilities that perform velocity vector and Euler angle transformations are written for a format similar to that above. The velocity vector conversion program requires the inputs to be in meter/sec units and the Euler angle conversion program requires the inputs to be in degrees representing the roll, pitch, and yaw of an entity.

3.2.4.1.2 Limitations

These conversion utilities have their limitations in analyzing large sets of data. For example, if numerous PDUs must be transformed from one coordinate system to another, it takes a substantial amount of time to input each set of coordinates into the test program. These utilities are not designed to read data from a data logged file.

Another limitation occurs in transforming coordinates located in the North and South Pole regions of the ellipsoidal earth. The programs do not take these special cases into consideration. Care must be taken if the geocentric coordinate X equals zero.

Due to time constraints, the utilities are written to support only the Fort Hunter-Liggett terrain database. In order to accommodate other databases, simple modifications to these conversion utilities are required.

3.2.4.2 Timestamp Analysis Utility

A timestamp analysis utility was developed to interpret the 32-bit unsigned integer timestamp field defined in the DIS PDUs. In DIS, the timestamp is defined to represent the units of time passed since the beginning of the current hour, with the least significant bit indicating whether the timestamp is absolute or relative. A relative timestamp was used at the I/ITSEC demonstration because of the absence of a global network timing mechanism.

3.2.4.2.1 Usage in Testing

As the most significant 31-bits of the timestamp field determines the units of time passed since the beginning of the current hour, this number is multiplied by 1.676 microseconds to calculate the time passed in microseconds. This final value is divided by 1000000 to equate the time in units of seconds. The purpose of the timestamp utility is to calculate the difference in time passed between two consecutive DIS PDUs.

The utility requests the values for two timestamp fields (in the format defined in the DIS PDUs) and calculates the difference in seconds between the two times. This utility was used at I/ITSEC to help examination of dead-reckoning models used in a particular simulator.

3.2.4.2.2 Limitations

Like the coordinate conversion utilities, the timestamp analysis utility is not designed to read input data from a data logged file. This utility is used only for random samples of timestamps obtained from the Entity State PDUs.

3.2.5 TSI Protocol Translator and Stealth

IST used a protocol translator (PT) manufactured by Technology Systems, Inc., P.O. Box 717, Water Street, Wiscasset, ME 04578. The translator allows a limited interaction between SIMNET and DIS simulators by logically connecting a SIMNET LAN with a DIS LAN.

A "Stealth Display", or "Magic Carpet" is an image generator configured to produce a 3-dimensional, perspective graphics, out-the-window type of display of a virtual environment. A Stealth's viewpoint is typically controlled manually but can sometimes be assigned to mimic the view of a simulated entity which it tracks, or to "attach" to an entity to follow it as it moves. IST used a Stealth which was also developed by TSI.

The PT and Stealth are combined in one computing platform. The hardware consists of an 80386 AT type PC clone with several plug-in boards based on Transputers, the Intel I860, and XTAR graphics hardware to facilitate Ethernet communication and visual rendering. In addition, the PC includes an 80387 math coprocessor, trackball, and joystick. The Stealth display is rendered on a 33-inch multisync Mitsubishi color monitor. All of the equipment is housed in a wheeled cabinet.

3.2.5.1 Protocol Translator

The function of the PT is to provide bidirectional translation and retransmission of a subset of the DIS PDUs and SIMNET PDUs appearing on each of the two LANs it monitors. The PT converts between the four DIS (Version 1.0 May 8 1991) PDUs:

- Entity State
- Fire
- Detonation
- Collision

and the five SIMNET (Version 6.6.1) PDUs:

- Vehicle Appearance
- Fire
- Impact
- Indirect_fire
- Collision

In order to convert between spatial coordinate systems the PT uses a version of the Hunter-Liggett terrain database.

3.2.5.1.1 Usage in Testing

Because the PT was part of the IDA entry in the I/ITSEC demonstrations, it was also required to pass certification tests and was, therefore, not used to help in the validation of other systems until later in the testing process.

During the I/ITSEC demonstrations the PT was used to provide the IDA Stealth with SIMNET network traffic for display.

In the latter stages of testing, the IDA Stealth was used to observe the participants' entities to determine correctness of attitude and appearance that had not been easily examined using the other test tools.

3.2.5.1.2 Limitations

The PT has a number of limitations that affect its usefulness as a test tool. Some of the limitations are apparent in the cases where there is not a one-to-one mapping between fields in the two protocols.

For example, there are no fields in the DIS Detonation PDU to represent the information in the SIMNET Impact PDU's momentum, energy, and directionality fields. In the production of the SIMNET PDU, values for these fields must be inferred, computed or set to reasonable defaults. All of the same entity types are not accounted for in each protocol. For example, a BREM1 is not defined in DIS and has to be defaulted to a T72.

Another shortcoming is the limited throughput rate. Although advertised as translating approximately 600-1000 PDUs per second, the actual rate is closer to 240. This is largely due to the expense of the computations for coordinate translation.

The PT attempted to mitigate problems with miscorrelation of Terrain Databases by "planting" ground entities on the copy of the Terrain Database it maintained internally. This Terrain Database matched fairly closely the one used by the IDA Stealth but, as a result of the "planting" and of incomplete software development, some locations in Fire and Detonation PDUs were not appropriately translated. Therefore muzzle blasts and weapons impacts did not usually match the locations of the muzzles or the targets.

3.2.5.2 Stealth

The TSI Stealth provides a 3-D perspective view of a simulation, based upon eye location and orientation controlled by a trackball and joystick, or by the location of an entity it has been commanded to follow. Depth of view is 3500 meters and the frame rate is 15Hz +/- 3Hz. The aperture is equivalent to that of a typical 35mm camera.

When attached to an entity four tether modes are available. These are called Orbit, Compass, Mimic and Tactical. With the Stealth, a user can visualize the orientation (roll, pitch and yaw) and location of simulated entities.

3.2.5.2.1 Usage in Testing

For the same reasons as the PT, the Stealth was not used to validate other systems until late in the testing stages. The most significant discrepancy, which was not detected until late in testing, was a reversal of roll angle in the display of entities. Once the problem

was fixed, the STEALTH was used in testing and was helpful in detecting attitude errors that were difficult to detect with a 2-D visual system.

3.2.5.2.2 Limitations

There were some limitations with the Stealth system. First, a number of different entities were displayed using the same icon. For example, most ground based vehicles were displayed as an M1 tank. Secondly, as a result of the design of the operator interface, it is extremely difficult to locate a particular entity and attach to it. Slew rates are very low and as a result, considerable time and care is required to approach a moving vehicle in order to attach to it, especially in the case of fast moving aircraft.

3.3 Test Methods

IST had established a working testbed available to test participants for the I/ITSEC demonstration by 17 August 1992. Three methods of testing were available to organizations: in-house, where the organization could physically locate their equipment in the labs at IST; by exchanging files generated by a copy of the IST data logger (described in Section 3.2.2); or using the (800) dial-up service described in Section 2.2.1.2.

The last day for testing with IST (via dial-up or in-house) was Tuesday, 20 October 1992. IST was not available the remainder of the week due to packing and shipping equipment to San Antonio. IST did accept data logged streams through Thursday, 22 October.

Four organizations (Grumman, NTSC, IBM, and IST) tested in-house prior to the I/ITSEC test week. However, none of these organizations passed all tests per the test plan.

There were six organizations which tested with IST via data logged streams (CAE-Link, BBN, Hughes, GD Land, Mak Technologies, and Lockheed-Sanders). Due to the limited amount of this type of testing, most SUTs could only get through the PDU level tests. IST also made logged data streams available via the ADST bulletin board. These streams were for network and PDU level tests only.

No organizations tested via the (800) number service; although, two organizations got as far as connecting to IST's LAN via the NetBlazer.

3.4 Test Policies and Procedures

The following information describes the testing policies that IST used during the I/ITSEC demonstration.

3.4.1 Test Conductors

To ensure fair and impartial testing of each participant, all tests were conducted by an IST employee. Players who had already passed tests helped others to solve their problems, but they did not make decisions as to the acceptance or rejection of other player's systems.

3.4.2 Test Periods

For testing, time slots were allocated in two hour periods during the test week and in one hour periods during the demonstration week. If testing had not been completed by the end of the test period, the company was put at the bottom of the queue. A company could resume testing on their next turn.

Test periods were two hours per simulator. If a company brought more than one system (send/receive or receive only), EACH system had to pass the test plan. In other words, a company with four simulators required four, two hour test slots. As soon as one (of the four) systems passed all the tests, the company could use the remaining time in the two hour block to begin testing the next system.

3.4.3 Order of Testing

To ensure that the maximum number of companies participated in the demonstrations, IST established guidelines for the order in which companies (players) were tested. The following guidelines were used during both weeks:

- Companies which had previously tested with IST (via the (800) numbers, data logged tape, or in-house) had the highest priority. This distinction was made for two reasons:

  First, IST had some knowledge of these systems and had already assisted the player with debugging and these players had the highest probability of continuing to the plenary demonstration. Second, as players "passed" the tests, they were able to assist other players resolving problems.

  The testing order was determined as follows:

  1) Companies which had passed all tests were the first systems connected to the network. If more than one company had passed all tests, they were connected in the order in which they passed (i.e., the first company that passed all tests was the first company connected).

2) Companies which had passed some tests were the next group connected to the network. The testing order was based on the number of tests passed (e.g., a company which passed four out of the five tests was tested before a company which passed only two out of the five tests).

- The companies which had never tested with IST (via dial-up, data logger, or in-house) had the lowest priority and their testing order was then determined by a lottery.

3.4.4 Testing Hours

Due to the large number of simulators that required testing, IST and participants had to work a 24 hour schedule. IST ran two 12 hour shifts with two test teams on each shift. IST's test teams were as follows:

Shift 1 (noon-midnight)	Shift 2 (midnight-noon)
Bruce McDonald	Brian Goldiez
Margaret Loper	Scott Smith
Huat Ng	Gamini Bulumulle
Mikel Petty	Michael Craft
David Van Brackle	David Shen
Karen Danisas Williams (STRICOM)	Jon Watkins

Two test teams allowed systems to be tested in parallel. With this schedule, the first round of testing required approximately 32 hours. Testing began Monday the 26th at 11:30 p.m. Due to the power failure all day Tuesday (10:00 a.m.-11:00 p.m.), the first round of testing finished sometime Wednesday night. Testing continued through Friday.

As systems passed ALL tests, they began practicing scenarios with Dan Mullally of IST. This began on Friday. Testing ended Saturday the 31st at noon. All participants then moved their equipment to the southeast hall. Any systems which had not passed their tests or any late comers had until Sunday morning to continue testing. The remaining time was devoted to practicing scenarios.

Due to the large number of simulators (43) that had to be tested in San Antonio and the limited amount of time to accomplish this feat, IST set the "Last Call" for demonstration participation at midnight, Saturday the 31st. However, because of the extended time spent in the gallery hall on Saturday, last call was extended to Sunday morning. This meant that any system which had not passed all tests by Sunday morning could not participate in the opening plenary or banquet demonstrations. Schedule constraints dictated that if a system did not pass all tests by Sunday, it could only participate in 30 minute reserved slots.

3.4.5 Portable Testbed

IST used portable testbeds (i.e., PCs on wheels) to perform testing throughout the two weeks at I/ITSEC. The testbeds were used to test systems in an isolated environment. Guidelines for the use of the testbed appear in Section 3.4.3.

3.4.6 Order of Tests

Tests were performed in the following order: network, PDU, terrain, appearance, and interactivity. Following these tests, participants began scenario testing.

1) TEST PLAN TESTS
These tests consisted of the network, PDU, terrain, appearance, and interactivity tests outlined in the test plans. Initially, tests were conducted one player at a time (in isolation) following the "Order of Testing" rules outlined above. This allowed IST and the SUT to debug software with the maximum number of variables held constant. After each SUT passed the range of test plan tests, it could connect to the main network to begin practicing.

2) SCENARIO TESTS
Once every player had been verified as capable of speaking and understanding DIS, scenario practice began using the scenarios developed by IST. Each venue was given time on the IDA Stealth to develop scenarios.

3.4.7 Multiple Networks

During both weeks, the capability existed to divide the network into multiple subnetworks. This provided a way to practice scenarios in more than one venue at a time. During the first week, the subnets were divided by air, sea, and land. This allowed like entities to practice together. During the second week, the subnets were used in debugging the showroom floor network. The division was the eight subnets connected by the repeater hub.

3.4.8 Criteria for Participating in Demonstrations

The following criteria were used to determine if a simulator could participate in the opening plenary and pre-banquet demonstrations. The criteria were applied to both simulators and listen-only devices:

- Successful completion of tests (1) and (2) described above, and

- Each venue (land, sea, air, and listeners) determined mutually beneficial criteria for participating in the scheduled demonstrations. A system had to satisfy the criteria determined by its working group. In the event that no minimum requirements were set by a venue working group, the test plan served as the criteria for participation;

A system could participate in the scheduled demonstrations if, and only if, it passed both of the criteria stated above.

In San Antonio, participant meetings were held at noon everyday. These meetings were used to discuss the current state of testing. Subjects included differences in terrain, tolerances for appearance tests, and assessment of interactivity tests. At these meetings, IST let participants decide what was, and was not, acceptable for the demonstrations. Issues were decided by majority vote. Only those companies on the Action/Decisions list had a vote, with one vote per company. This system was used to address discrepancies between simulators or within a single simulator.

Every company had the "first right of refusal" for their system(s). The second right of refusal belonged to the group. A majority vote could exclude a company from the demonstrations as well as allow it to participate even if it could not meet the minimum requirements stated in the test plan. IST made every attempt to keep a level playing field for all participants. The goal was to have the maximum number of participants in the demonstrations.

3.5 Test Results

The diverse nature of the various components of interoperability required varied testing. Testing was accomplished at differing levels of networked simulation to help isolate interoperability problems. A variety of test batteries were required for the different types of systems. For example, tests for CGF had to be performed not just for one type of entity (e.g., M1), but for one entity of each type (land, sea, and air) that the SUT could generate. Also, tests for vehicle simulators were not appropriate for systems that simply listened to network traffic. Some flexibility was allowed for determination of interoperability due to the divergent nature of the systems. The basic interoperability concepts were tested, but different tests were required for the various types of systems, as shown in Table 7.

Following the test policies for test periods and testing order (Sections 3.4.2 and 3.4.3), each SUT was subjected to the tests stated in the reduced scope test plan. Each SUT's test data was logged in text and binary form using the IST PC-based data logger. Data was also recorded on test sheets. See Appendix G. All logged data was stored on 3.5"

disks and then analyzed by a member of the IST test team using the test tools described in Section 3.2. IST testers were able to give immediate feedback on some tests, for example, incorrect timestamps, multiple collision generation, etc. However, turn-around on formal test results was on the order of hours (sometimes as long as 8). After a SUT had passed the full range of tests, the test results were presented to the shift leader (Brian, Scott, or Bruce) to be signed-off. The pass list was posted outside of the IST booth.

The desensitized test data for S/R and SO devices are presented in Tables 8-12. Because LO devices only had to receive data, there are no test results per se. Several interesting comments can be made about Stealths, however. Entities that IST test systems generated for Stealth testing often appeared underground or flying. Entities also often appeared incorrectly on the SUT. This was usually due to incorrect mapping of entities in protocol translators or network interface units. The only Stealth which had to correct all problems of this nature was IDA's, as it was used for viewing the demonstrations.

NAME OF TEST PERFORMED	TYPE OF SUT TESTED			
	LAND	SEA	AIR	LISTEN ONLY
NETWORK				
Broadcast	RQ	RQ	RQ	Not RQ
Unicast	*	*	*	Not RQ
ARP	RC	RC	RC	RC
PDU				(Receive Only)
Entity State	RQ	RQ	RQ	RQ
Fire	RQ	RQ	RQ	RQ
Detonation	RQ	RQ	RQ	RQ
Collision	RQ	RQ	Not RQ	RQ
TERRAIN ORIENTATION				
Orientation Transmission	RQ	RQ	RQ	Not RQ
APPEARANCE TESTS				(Receive Only)
Location	RQ	RQ	RQ	Not RQ
Attitude	RQ	RQ	RQ	Not RQ
Dead Reckoning	RQ	RQ	RQ	Not RQ
Entity Type Validation	RQ	RQ	RQ	RQ
Articulated Parts	RQ	Not RQ	Not RQ	Not RQ
INTERACTIVITY TESTS				
Maneuver, Shoot, Kill	RQ	RQ	RQ	Not RQ
Collision	RQ	RQ	Not RQ	Not RQ

Table 7: Required Tests for SUTs
(RQ = Required, RC = Recommended, * = SUT dependent)

	Broadcast Tests		Unicast Tests		ARP Tests	
SUT	Test Performed	# Times to Pass	Test Performed	# Times to Pass	Test Performed	# Times to Pass
A	Yes	1	No	N/A	Yes	1
B	Yes	1	Yes	1	Yes	1
C	Yes	2	No	N/A	Yes	1
D	Yes	1	No	N/A	Yes	Never
E	Yes	3	No	N/A	Yes	1
F	Yes	1	No	N/A	Yes	1
G	Yes	1	No	N/A	Yes	1
H	Yes	1	Yes	1	Yes	2
I	Yes	2	Yes	2	Yes	1
J	Yes	1	Yes	1	Yes	1
K	Yes	1	Yes	1	Yes	1
L	Yes	1	Yes	1	No	N/A

Table 8: Network Level Test Results (S/R and SO)

	Broadcast Tests		Unicast Tests		ARP Tests	
SUT	Test Performed	# Times to Pass	Test Performed	# Times to Pass	Test Performed	# Times to Pass
M	Yes	1	No	N/A	Yes	1
N	Yes	1	No	N/A	No	N/A
O	Yes	2	No	N/A	Yes	1
P	Yes	2	No	N/A	Yes	1
Q	Yes	1	No	N/A	Yes	Never
R	Yes	2	No	N/A	Yes	1
S	Yes	1	No	N/A	Yes	2

Table 8 (Cont'd): Network Level Test Results (S/R and SO)

	Entity State		Fire		Detonation		Collision	
SUT	# Times to Pass	Problem Fields	# Times to Pass	Problem Fields	# Times to Pass	Problem Fields	# Times to Pass	Problem Fields
A	3	Time, Entity type	3	Mun. type	3	Target ID, Mun. type	2	Entity ID
B	2	Entity ID, Art. parts change #	2	Mun. ID	1	None	1	None
C	2	Pkt. too long	1	None	1	None	1	None
D	1	None	N/A	N/A	N/A	N/A	N/A	N/A
E	2	Hatch open, Art. parts	1	None	2	Attack ID, Event, Art. parts, Vel.	2	Event, Loc.
F	1	None	1	None	1	None	1	None
G	1	None	1	None	1	None	N/A	N/A
H	2	Art. parts	1	None	1	None	1	None
I	2	Pkt. too long	2	Tgt. ID	2	TgtID	N/A	N/A
J	2	Entity type	2	EvntID, burst	2	EvntID, burst	1	None

Table 9: PDU Level Test Results (S/R and SO)

	Entity State		Fire		Detonation		Collision	
SUT	# Times to Pass	Problem Fields	# Times to Pass	Problem Fields	# Times to Pass	Problem Fields	# Times to Pass	Problem Fields
K	1	None	1	None	1	None	1	None
L	Signed Off	Timestamp	Signed Off	Time, EvntID, burst Mun.	Signed Off	Time, EvntID, burst Mun.	N/A	N/A
M	2	Time, ForceID, entity type, DR, orien.	1	N/A	1	N/A	N/A	N/A
N	2	EntityID, ForceID	N/A	N/A	N/A	N/A	N/A	N/A
O	2	EntityID, Art. parts, Time	2	Attack. ID	2	Attack. ID, EvntID	2	IssueID
P	2	EntityID, Art. parts, Time	2	Attack. ID	2	Attack. ID, EvntID	2	IssueID
Q	1	N/A	2	Vel.	2	Vel.	N/A	N/A
R	2	Entity type, Time	N/A	N/A	N/A	N/A	2	Vel., Loc.
S	1	N/A	1	N/A	1	N/A	1	N/A

Table 9 (Cont'd): PDU Level Test Results (S/R and SO)

	Orientation Tests		
SUT	# Times to Pass	Visual Verification Made	Problems Encountered
A	1	Yes	None
B	1	Yes	None
C	3	Yes	90° Off
D	2	Yes	None
E	1	Yes	None
F	1	Yes	Orientation, Timestamps
G	1	Yes	None
H	1	Yes	None
I	1	Yes	None
J	1	Yes	None
K	1	Yes	None
L	1	Yes	None

Table 10: Terrain Orientation Level Test Results (S/R and SO)

	Orientation Tests		
SUT	# Times to Pass	Visual Verification Made	Problems Encountered
M	Signed Off	Movement was Jumpy	DR in Wrong Coordinate System
N	3	Yes	Velocity
O	2	Yes	Timestamp
P	2	Yes	Timestamp
Q	2	Yes	Timestamp
R	1	Yes	None
S	2	Yes	Velocity

Table 10 (Cont'd): Terrain Orientation Level Test Results (S/R and SO)

	Location Tests			Attitude Tests		Dead Reckoning	
SUT	# Times to Pass	Position Tolerance	Rate of ESPDUs	# Times to Pass	Problems Encountered	# Times to Pass	Meet 1m Tolerance
A	2	1m	4.998s	1	None	2	Yes
B	1	1m	3.63s	1	None	1	Yes
C	1	1.3m	4.299s	N/A	N/A	1	Yes
D	2	1m	5.018s	3	Yaw	2	Yes
E	1	1m	5.01s	1	None	1	Yes
F	3	1m	5s	1	Orien.	3	Yes
G	1	1m	4.998s	1	None	1	Yes
H	1	1m	4.359s	2	Attitude	1	Yes
I	1	1m	5s	1	None	2	Yes
J	2	1m	5s	1	None	1	Yes
K	1	1m	5s	1	None	1	Yes
L	Signed Off	N/A	N/A	Signed Off	N/A	Signed Off	No

Table 11: Appearance Level Test Results (S/R and SO)

	Location Tests			Attitude Tests		Dead Reckoning	
SUT	# Times to Pass	Position Tolerance	Rate of ESPDUs	# Times to Pass	Problems Encountered	# Times to Pass	Meet 1m Tolerance
M	2	N/A	4.99s	1	None	Signed Off	No
N	Signed Off	2,3-6m	N/A	3	Erratic Mvmt, always pointed N	Signed Off	No
O	2	1m	5s	2	Timestamp	2	Yes
P	2	1m	5s	2	Timestamp	2	Yes
Q	2	1m	5s	1	None	2	Yes
R	1	1m	5s	1	None	1	Yes
S	1	1m	4.99s	2	Vel.	2	Yes

Table 11 (Cont'd): Appearance Level Test Results (S/R and SO)

	Entity Type Validation			Articulated Parts	
SUT	# Times to Pass	How Many Entities Were Generated	Able to Receive All Entity Types	# Times to Pass	Problems Encountered
A	1	4	Yes	N/A	N/A
B	1	over 100	Yes	2	BAMS
C	1	5	Yes	N/A	N/A
D	Signed Off	2	No	N/A	N/A
E	1	9	Yes	2	Chg. indicator, BAMs, Gun elev.
F	1	1	Yes	1	None
G	1	2	Yes	N/A	N/A
H	1	15	Yes	2	BAMs
I	1	1	Yes	N/A	N/A
J	1	1	Yes	1	None
K	1	1	Yes	1	None
L	1	1	Yes	N/A	N/A

Table 11 (Cont'd): Appearance Level Test Results (S/R and SO)

	Entity Type Validation			Articulated Parts	
SUT	# Times to Pass	How Many Entities Were Generated	Able to Receive All Entity Types	# Times to Pass	Problems Encountered
M	1	1	Yes	N/A	N/A
N	1	1	Yes	N/A	N/A
O	1	2	Yes	N/A	N/A
P	1	2	Yes	N/A	N/A
Q	1	2	Yes	N/A	N/A
R	1	1	Yes	N/A	N/A
S	1	1	Yes	2	Chg. field

Table 11 (Cont'd): Appearance Level Test Results (S/R and SO)

	Maneuver, Shoot, Kill				Collision	
SUT	# Times to Pass	ES, F, & D PDUs Produced in Correct Order	Did SUT Die	Problems Encountered	# Times to Pass	Problems Encountered
A	4	Yes	Yes	Not close enough	2	Entity ID
B	1	Yes	Yes	None	2	Velocity
C	1	Yes	Yes	None	1	None
D	N/A	N/A	No	N/A	N/A	N/A
E	3	Yes	Yes	None	2	EvntID
F	1	Yes	Yes	None	1	EvntID
G	2	Yes	No	Finding Tgt.	N/A	N/A
H	1	Yes	Yes	None	1	None
I	1	Yes	No	None	N/A	N/A
J	2	Yes	Yes	Result field in DPDU	2	Multiple PDUs
K	1	Yes	Yes	None	1	None
L	Signed Off	N/A	N/A	N/A	Signed Off	N/A

Table 12: Interactivity Level Test Results (S/R and SO)

	Maneuver, Shoot, Kill				Collision	
SUT	# Times to Pass	ES, F, & D PDUs Produced in Correct Order	Did SUT Die	Problems Encountered	# Times to Pass	Problems Encountered
M	N/A	N/A	Yes	N/A	N/A	N/A
N	N/A	N/A	No	N/A	N/A	N/A
O	2	Yes	Yes	None	2	None
P	2	Yes	Yes	None	2	None
Q	1	Yes	Yes	None	N/A	N/A
R	N/A	N/A	Yes	No Weapons	3	Multiple PDUs, Veh. Dynamics
S	1	Yes	Yes	None	2	Multiple PDUs

Table 12 (Cont'd): Interactivity Level Test Results (S/R and SO)

A summary of the test results is shown in Tables 13-17. The test results revealed the following:

- While the reduced scope test plan was simple and straightforward, no SUT's were able to pass all tests on the first pass. This is not surprising because no formal testing for DIS has ever taken place. However, as the test plan moves from reduced scope to full compliance, the tests will become more complex and will take even more time to conduct and pass.

- There were a number of fields in the four PDUs which were consistently interpreted incorrectly. This required companies to modify their software in order to pass the tests. The areas of the DIS standard that were interpreted incorrectly should be reviewed by the Interface/Time Mission Critical working group. Modifications should be made to the standard (where necessary) to more fully describe what data belongs in these fields. The most commonly misinterpreted fields are shown below:

Entity Type	Munition ID
Entity ID	Target ID
Articulated Parts	Event ID
Force ID	Attacker ID
Munition Type	Issue ID
Result (DPDU)	

- In addition to misinterpreted fields, several elements of the DIS standard were not well understood by demonstration participants. This caused much frustration and often led to "tutorials" by IST and other participants. More information on these issues (shown below) should be included in the standard or rationale document.

Timestamps	Collisions
Dead Reckoning	BAMs[6]
Coordinate Conversions	

[6] This is a non-issue with the IEEE version on the DIS standard. BAMs have been replaced by radians.

Broadcast Tests	Unicast Tests	ARP Tests
# Times to Pass	# Times to Pass	# Times to Pass
1 Time = 13 2 Times = 5 3 Times = 1	6 Companies: 1 Time = 5 2 Times = 1	17 Companies: 1 Time = 13 2 Times = 2 Never = 2

Table 13: Summary of Network Level Tests

Entity State		Fire		Detonation		Collision	
# Times to Pass	Problem Fields	# Times to Pass	Problem Fields	# Times to Pass	Problem Fields	# Times to Pass	Problem Fields
1 Time = 6 2 Times = 11 3 Times = 1 Never = 1	Time, EntTyp, EntID, ArtPts, ForcID, DR	1 Time = 8 2 Times = 6 3 Times = 1 Never = 1 N/A = 3	MunTyp, MunID, TgtID, EvntID, AttkID	1 Time = 8 2 Times = 6 3 Times = 1 Never = 1 N/A = 3	TgtID, MunTyp, AttkID, EvntID, ArtPts, Vel.	1 Time = 7 2 Times = 5 N/A = 7	EntyID, Evnt, Loc., IssID, Vel.

Table 14: Summary of PDU Level Tests

Orientation Tests	
# Times to Pass	Problems Encountered
1 Time = 11 2 Times = 5 3 Times = 2 Never = 1	Timestamps, Orientation, DR in wrong Coordinate System, Velocity

Table 15: Summary of Orientation Level Tests

Location Tests		Attitude Tests		Dead Reckoning
# Times to Pass	Rate of ESPDUs	# Times to Pass	Problems Encountered	# Times to Pass
1 Time = 9 2 Times = 7 3 Times = 1 Never = 2	High = 5.01s Low = 3.63s	1 Time = 11 2 Times = 4 3 Times = 2 Never = 1 N/A = 1	Yaw, Orientation, Attitude, Timestamp, Always Pointed N, Velocity,	1 Time = 8 2 Times = 7 3 Times = 1 Never = 3

Table 16: Summary of Appearance Level Tests

Entity Type Validation		Articulated Parts	
# Times to Pass	How Many Entities Were Generated	# Times to Pass	Problems Encountered
1 Time = 18 Never = 1	From 1 to 100	1 Time = 3 2 Times = 4 N/A = 12	BAMs, Gun Elevation, Chg. Field

Table 16 (Cont'd): Summary of Appearance Level Tests

Maneuver, Shoot, Kill			Collision	
# Times to Pass	Did SUT Die	Problems Encountered	# Times to Pass	Problems Encountered
1 Time = 8 2 Times = 4 3 Times = 1 Never = 1 N/A = 4	Yes = 14 No = 4	Result Field in DPDU, Finding Tgt.	1 Time = 4 2 Times = 7 3 Times = 1 Never = 1 N/A = 6	EntityID, Velocity, EventID, Multiple PDUs, Vehicle Dynamics

Table 17: Summary of Interactivity Level Tests

4. 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 reduced scope or partial test documents, 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 correlation or DIS. For example, floating tanks in a visual scene could be the result of incorrect coordinate transformation, incorrect dead reckoning, or correlation problems between rendered data bases. 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 simulator capabilities. IST believes the lack of simulator information was due to the participant's 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 tests 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 reason is 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 rotate 90° up 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 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 adverse or erroneous conditions. 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.

4.1 Network

The demonstration network was installed on Sunday, November 1. The installation began at 6:00 a.m. and was not complete until approximately 6:00 p.m. when the convention center opened to the public. Prior to setting up the network, IST checked all cables with the HP Analyzer for breaks and bad connections. (It became evident this was not a thorough enough test.) Unbeknownst to IST, forklifts were still running on Sunday. This slowed the installation so that periodically during the day, IST had to go "fix" cut cables and broken connectors which had been caused by the forklifts. In addition, IST ran out of cables and BNC connectors. IST underestimated the amount of cable required for the convention center. Also, more cables were used and damaged during the rehearsal week than had been expected. Of course, on a Sunday stores were not open to purchase spares.

When the network was "turned on" Sunday evening, only four of the eight legs were working (Legs 1, 4, 5, and 6 shown in Figure 3). As soon as the problems with the network became apparent, IST was approached by BBN, IDA, and Concurrent Computer to assist in isolating network faults. IST was reluctant to accept help from anyone else because it was feared that too many people going in separate directions would make diagnosing the problems more difficult. IST used a methodical, sequential debugging approach which was felt to be more effective than many uncoordinated efforts.

The test team corrected the problems with Legs 2, 3, 7, and 8. The remaining legs were double-checked to ensure network integrity. The network was up and working by 1:00 a.m. Monday morning.

In discussions after the demonstration, the following comments and recommendations were made:

- BBN recommended measuring exact cable lengths once booth boundaries are marked (prior to vendors moving in). They strongly discouraged splicing standard lengths with barrel connectors, especially when these connectors might be underneath carpets or in other relatively inaccessible places. More attention should be paid to using the correct end fittings when building cables. Many more spare parts should be on hand. BBN has had good luck subcontracting cable manufacturers when they have had these exact measurements. Connections are better made and there are companies that are set up to do this job quickly;

- All cables should be clearly labeled at both ends;

- A much larger, much more detailed floor plan diagram should have been made. It should show every barrel, T, terminator, length, etc. There should be multiple copies made because loss of the original could result in extreme delays in troubleshooting;

- More multimeters should have been available and more individuals should have known how to use them to test for continuity, intermittent connections, shorts, etc; and

- To avoid this problem in the future, it may be better to string network cable on overhead "telephone poles."

In support of the ideas described above, IST believes that two documents should be developed prior to another demonstration:

<u>Implementation Plan</u>

A plan which describes how to setup the network. For example, it should include maps of the showroom floor with exact booth boundaries, what length cables should be used on which legs, how legs should be installed, how the cable should be labeled for easy debugging, how each leg should be tested while being installed, etc. The plan would expedite the network installation and make maximum use of human resources; and

Backup Strategy

There will always be unforeseen problems which come up during the installation of the network (e.g., moving fork lifts, carpet layers with knives, etc.) A plan for methodically testing the network and isolating problems is essential.

Network latency has never been an issue or measured in DIS. As network sizes grow and long haul communications become more commonplace, network latency issues will grow. Network latency measurement techniques and mitigation methods should be investigated.

4.2 DIS Standard

The DIS Standard was taken at face value for this demonstration. As far as IST knew, this was the first implementation of the DIS Standard. If the standard had been previously implemented, no data was available for review. The DIS Standard had also not been evaluated and documented in an experimental or laboratory setting. Therefore, there were occasions when taking the Standard at face value was not advisable. An example of such a situation was in the use of geocentric coordinates. IST spent a considerable amount of time assisting participants with conversion routines. IST and the organizations participating in the demonstration learned that conversion routines should be standardized if coordinate transformations are going to be used. IST and participants also learned that numerous coordinate transformations consume valuable computer resources and result in loss of data content with each transformation.

Based on comments made by demonstration participants, there are a number of areas in which the DIS 1.0, May 8 standard is incomplete, confusing, vague, or internally inconsistent. The following ambiguities in the standard were identified:

- Dead Reckoning caused 58% of SUTs to fail Appearance Level tests on the first try. Problems included incorrect velocity and timestamps and dead reckoning in different coordinate systems;
- Right Hand Rule was interpreted differently and caused aircraft turning in like directions to bank in opposite directions;
- Impact Result in the Detonation PDU was interpreted differently by SUTs resulting in entities continuing to live who should have actually died, and vice versa;
- Coordinate Systems conversion routines were generated by each company resulting in different position tolerances across SUTs;
- No specific "Deactivate" or "Remove Entity" PDU exists in DIS causing SUTs to create kludges for missiles (0 velocity, center of the earth); these are not long term solutions;

- BAMs, while not a problem in IEEE P1278, were misinterpreted causing SUTs, especially CGF systems, to fail the articulated parts test;
- Collisions were not understood by all SUTs and problems such as multiple PDU generation were a result; and
- State Diagrams that showed the relationship and sequence of PDUS (e.g., Fire and Detonation) were not available and caused confusion in some simulators.

Interoperability participants also felt that the following changes should be made to the standard:

- Make appearance bits consistent across entity types;
- Appendix H2 should be reordered in a more logical fashion, especially as regards ship classes;
- The hierarchy of munition types is not complete;
- Engine speed is not represented in DIS. This should be added to allow simulators to generate appropriate vehicle sounds for entities they track (this may be handled in the emissions PDUs?); and
- Explanation of the handling of articulated parts was incomplete, and the example in the appendix was misleading.

General comments made by demonstration participants were:

- Testing needs to be visually oriented. Examining data fields in packets does not reveal problems that are easily seen in 3-D visualization (e.g., tanks on their sides);
- Standard should discuss dead reckoning and smoothing;
- Smoothing covers problems. Jumping was caused by incorrect orientation and velocity vectors and also by dead reckoning in one coordinate system and broadcasting in another;
- PDU frequency also affects dead reckoning and smooth movement;
- There must be an effective way to deactivate missiles, and it should be specified in the standard. Current workarounds (0 velocity, center of earth are not satisfactory for long term). New munition types, such as cluster bombs, WAMs, multiple warhead missiles, etc. require changes to Fire and Detonation sequence;
- IST should collect coordinate transformation routines from participants and execute them to study errors in terrain correlation caused by these routines;
- It was not clear whether floating tanks were caused by terrain correlation, coordinate transformations, or dead reckoning; and
- Use known features with known lat/long to calibrate terrain.

Ideas for changes to DIS Standard:

- Add field to ES PDU identifying hierarchical organization of entity; and
- Investigate adding a ground clamping bit in ES PDU. Ground clamping can be useful. This can easily be achieved with a latitude, longitude, elevation coordinate system. Problems with Fire and Impact location may arise with partial implementations of ground clamping.

4.3 Terrain Representation

The data set developed for terrain was extremely large. Almost one gigabyte of data was provided for an area representing 100km x 100km. Segmentation of data into smaller sets would greatly facilitate data handling by a wide variety of hardware platforms and software routines.

Data was provided in three forms; post, polygons, and vectors. Some data, in particular vector data, was often provided in offset form. An offset provides the origin of the vector and its end point is described in the offset coordinate system. Offsets provided problems in that the algorithms used to offset the data from the data base origin were not given. Offset algorithms must be provided if cultural features are to be located consistently between simulators. The same matter applies to coordinate transformations, in general. For example, conversion routines used by P2851 to convert between UTM and geodetic were not provided for I/ITSEC and should be provided in future.

Fragmentation of polygons due to polygonization routines and overlaying of cultural features is a problem. P2851 recognized this problem and provided some guidance on solution methods. However, increases in polygon density due to fragmentation were not handled uniformly between participants. Part of the reason is image generator architecture oriented. Fragmentation can be handled many ways. The typical methods involve terrain relaxation (reducing the polygon density); adjusting image generator resources between models, culture, and terrain; or application of texture. While all of the above methods handle the fragmentation problem, the resulting image can differ greatly between simulators.

Correlation differences are the result of the above noted problems. P2851 helps, but will not solve the problem of correlation between visual systems. Unique data base development software, coupled with proprietary image generator rendering systems will always be a cause of correlation differences between rendered images. There is research going on in this area. However, the research must be oriented to quantifying the problem and then developing approaches to solve correlation problems BEFORE the data base is built. Current approaches address differences between data bases. Such approaches require that two data bases be built. This is a costly and time consuming process. It does little good to find out that data bases do not match after the data base has been

fabricated. Tools are needed to guide the designers while the data base is being developed.

A full report by PRC, detailing the lessons learned from the I/ITSEC demonstration, can be found in Reference [7].

4.4 Other Demonstrations

The majority of the organizations were interested in participating in another interoperability demonstration; however, some questioned whether I/ITSEC was the only forum that should be considered. When asked what capabilities should be demonstrated next year (i.e., I/ITSEC 1993), the following ideas were suggested:

- DIS standard version 2.0, emissions and communications PDUs;
- vertical integration: simulators, war-games, live vehicles;
- more entities (at least 200);
- multicast or filter by exercise IDs;
- different entity types, including non-military entities (e.g. emergency management);
- NTC participation;
- graphical display of network configuration and traffic;
- more scenarios;
- free play, with participants reacting to Detonation PDUs;
- long haul networking; and
- international participants (confusion over clearances reduced international participation this time);

General comments made about planning for another demonstration included:

- Don't allow late players to reduce demonstration scope. Set baseline standard and require all participants to adhere;
- Let everyone participate, even if they are limited;
- Have the visual system available for testing earlier and ready for the other participants immediately;
- Demonstration should have theme: such as Louisiana Maneuvers (which is not America and Allies) or interaction of virtual, constructive and live simulations;
- Have an audience participation simulator;
- Use enhanced Hunter-Liggett data base; add synthetic data to terrain database to make it more interesting;
- Need long-haul testing with a higher data rate than (800) numbers; and
- Use the Defense Simulation Internet as means of performing long-haul networking for testing.

5. CONCLUSIONS

Organizations should study each DIS PDU carefully before they recommend new PDUs. The standard is very rich in content and can accommodate a number of situations not originally intended. The situations cover a broad range from the specific use of existing PDUs to cover aggregated military units to the use of DIS in non-defense applications. Experimental evaluation and documentation of DIS is essential prior to promulgation of additional standards volumes. Organizations using standards look to the stability and validity of a standard as guiding principles. However, organizations must recognize that DIS and P2851 are developmental and subject to change. (See the PRC report Reference [7] for specific P2851 recommendations.)

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APPENDIX A

ACTIONS AND DECISIONS DOCUMENT

ACTIONS AND DECISIONS

FROM

SIMULATOR NETWORK DEVELOPMENT

FOR

A DEMONSTRATION OF DISTRIBUTED INTERACTIVE SIMULATION AND P2851

AT

THE INTERSERVICE/INDUSTRY TRAINING SYSTEMS & EDUCATION CONFERENCE

SAN ANTONIO, TEXAS

NOVEMBER 1-4, 1992

BACKGROUND

The Institute for Simulation and Training (IST) at the University of Central Florida was informally tasked in March, 1992 by the US Army Simulation Training and Instrumentation Command (STRICOM) and the Defense Modeling and Simulation Office (DMSO) to facilitate, design, and participate in a demonstration of Distributed Interactive Simulation (DIS) protocol data units and Project 2851 (P2851) terrain data bases. The demonstration was to take place during the Interservice/Industry Systems and Education Conference (I/ITSEC). The conference was to be held at the Gonzalez Convention Center in San Antonio, Texas from November 1-4, 1992.

The demonstration date of Noevember 1-4, 1992 was firm. However, the precise series of events necessary to meet the demonstration date was not known. Initially, IST believed that the design would be completed in July, testing would occur in August and September, correction of deficiencies would take place in September and October with set-up and demonstration at the conference in early November. These dates proved to be optimistic and too general. Indecision in participating on the part of organizations coupled with late availability of critical products resulted in the design being completed in late September. When it became apparent that the design would not be completed until this late date, a period of set-up, test and rehearsal in San Antonio became imperative. IST coordinated and and received approval for this rehearsal period from I/ITSEC officials.

IST was asked to solicit participation from as wide a group of participants as possible. IST was not to be concerned with funding for organizations participating in the demonstration. Solicitation by IST was conducted primarily through phone calls and two notices in the Commerce Business Daily.

The Commerce Business Daily notices were limited in content due to releasing the notice in a timely manner and because IST was not aware of the number of potential participants nor the true scope of the task at hand. IST called for a series of meetings to flesh out the details of the demonstration. The meetings would be held on essentially a monthly basis. The meetings would conducted to arrive at a plan, design, ground rules, etc. that met the needs of the majority of particpants.

A consensus based design was necessary. The Commerce Business Daily announcement contained requirements for testing, communications, and general participtiion. IST had no mechanism in place to enforce requirements levied on participants. Also, it was recognized that it would be difficult to distinguish participants from interested parties and observers. Therefore, although all monthly meetings were open, IST requested participants confirm their participation in writing. As time moved forward, participant comments held weight and priority over interested parties and observers.

It was not known, in advance, when participants would become sufficiently interested participating in the demonstration to make

the necessary financial and personnel commitments necessary to participate rather than observe. IST recognized that organizations would enter and leave the demonstration development process at various times which were not under IST's control. Therefore, a system was necessary to document open and closed design and programmatic matters. The systems was necessary to have a record of decisions made and open actions and to avoid lengthy explanations for interested parties who may be inteterested in becoming a demonstration participant. IST created a mechanism called Decisions and Actions. IST also made extensive use of Electronic Mail and Fax to keep participants informed of relevant information. Decisions and Actions were updated and distributed via Electronic Mail and Fax. Other information was also dissemenated through this mechanism.

The Decisions and Actions document respectively registers matters which have been resolved and those requiring some additional work prior to resolution. All matters which cannot be immediately dispositioned are called Actions. Actions are listed in the order which they occur, have a date noting when the matter was surfaced or when additional information was noted, have an individuals named noted who is to obtain information or analyze data to resolve the matter, and a reference to a decision to document the result of the action. Decisions note the disposition of matters which can be concluded immediately or have been resolved via an Action Item. Dates indicate when information became available for the decision. Reference to an Action is made where appropriate. The Decisions and Actions, which follow are listed in the order which they occur and have received only minor editing from their original version. Please note that several actions could be relevant to one decision.

REVISED: October 19, 1992

DECISIONS AND ACTIONS DOCUMENT
NOTES ON THE I/ITSEC INTEROPERABILITY DEMO MEETINGS
(Parentheses indicate date of note)

DECISIONS

DECISION 1: Voice - I/ITSC provides walkie talkies (multi-channel preferred) (4/10/92).

DECISION 2: Video taping - DDRE taping. Vendors may require approval & may tape themselves (4/10/92).

DECISION 3: Vendors will use existing characteristics of their weapons systems (4/10/92).

DECISION 4: IDA will develop scenarios (IST will provide support) (4/10/92).

DECISION 5: I/ITSC Interop. Demo Ground Rules (4/10/92)
- Demonstrate not evaluate
- Keep scope manageable
- Accumulate data
- Analyze results
- Minimize new development

DECISION 6: IST will define entity numbers for models if they are not in the current version of the standard (appendix) (4/10/92).

DECISION 7: All models (SIF or ASC11) must be provided to participants by July 15 (4/10/92). IST has many of the polygon models already. A list of current IST models will be provided on 5/19/92 (5/6/92). Ken Oda/PRC and Curt Lisle have gathered all models and are coordinating their delivery. Seventeen models should be delivered this week, and the remaining will probably be delivered next week (6/1/92).

IST has determined (based on limited discussions with visual vendors) that damage will be provided (visually) for man made culture (e.g., buildings, bridges), only. Moving models will only need a working and destroyed representation (5/6/92).
A decision was reached (5/19/92) that model developers will not provide damage icon models. Killed models will be painted Black (5/30/92). IST has also developed flash and smoke models (6/23/92). This closes ACTION items 11, 18, and 27 (6/23/92).

DECISION 8: IST will provide an operator to demonstrate different parts of the exercise. IST will try to give everyone equal time (on projection screen). Displays will also be shown on TSI's stealth and Grumman's radar display. Other participants will display the exercise in a manner consistent with their devices on

the network (4/10/92).

DECISION 9: Exhibit Hall for I/ITSC opens at 4:00 a.m., Saturday. IST can start dropping ethernet 12 noon on Saturday of I/ITSC (4/10/92).

DECISION 10: Bruce McDonald and Neale Cosby are the commanders (4/10/92). Based on scheduling and workload, IST may substitute another individual for Dr. McDonald in the future (5/6/92).

DECISION 11: Rules (4/10/92)
- Green is foe, brown is friendly, use force - id (6/23/92).
- Dead reckoning - 1st order.
- Thresholds - 1 cubic meter.
- No common activation point (operator), but IDA will initialize exercise.
- Destroyed models will be colored black in displayed visuals (5/19/92).
- A decision was reached to use DR thresholds: 3o 1m3.
Make models in three levels of detail (5/19/92).
- When you die, you cannot reconstitute (6/23/92).

DECISION 12: IST will assign host ID #'s to everyone (4/10/92).

DECISION 13: Hit assessment is up to each simulator (4/10/92). IST has access to the SIMNET damage models. IST feels that weapons models should be uniformly utilized in the demonstration. If they are not used uniformly, then one simulator may get a kill for a weapon when another simulator does not for identical conditions. SIMNET uses 30 degree sectors around a vehicles azimuth to compute hit or kill probabilities given a weapon type. Elevation is not considered (as far as can be determined by IST). This type of method is appropriate for ground vehicles, but not as realistic for air vehicles. However, adjusting the hit and kill probabilities can result in an acceptable portrayal of weapon effects. The SIMNET method will be explained on 5/19/92 with a request for participants to approve or disprove the method used (5/6/92).

IST will create a matrix delineating if a weapon has an effect on an entity. The extent of the effect will be up to the receiving entity per the DIS standard for Detonation (5/30/92). Participants will use the default values in the hit/kill matrix supplied by IST unless they have their own matrix. (6/23/92)See ACTION Items 13, 18, and 23 (5/6/92).

DECISION 14: Damage models (i.e. hole in a/c wing) will not be considered (4/10/92).

DECISION 15: Next meeting: May 19th (4/10/92)
Discuss:
- model sheets
- assignment of PDU fields
- network progress (UDP/IP)
- possible scenarios

DECISION 16: IST will work with NTSC to learn about UDP/IP for testbed conversion. If IST is unable to convert testbed in time for deadline on test stream data, NTSC will create test streams for participants. IST will handle the distribution of the test streams, whether generated by NTSC or IST (4/10/92).

DECISION 17: A decision was reached to use IP broadcast during the demonstration.

DECISION 18: IST will provide three levels of detail for the models to allow visual representation by various IG vendors in various degrees of fidelity (6/1/92).

DECISION 19: Any non-DIS traffic must be point-to-point to preclude any non-network traffic (5/19/92). Non-DIS traffic will be allowed on the network but must be transmitted point-to-point. IST will test for point-to-point transmission during interactive testing. Participants must expect to see ARP requests and respond to the ARP if the participant's simulator generates non-DIS traffic. Testing will include generating/responding to an ARP request (6/23/92).

DECISION 20: UDP port 3000 will be used in the exercise (5/19/92).

DECISION 21: UDP/IP, TCP/IP, and SIMNET Association have been under evaluation at IST. UDP/IP will be used. Systems integration could be a problem (4/22/92) if participants are not familiar with the inner workings of UDP/IP. UDP/IP was under evaluation at IST. NTSC test streams have been determined not to be appropriate for I/ITSC participants (4/22/92). Therefore, NTSC will not distribute the test streams (5/19/92). A protocol translator and a portable stealth will be procured by IST for the demonstration to assist software debug. IST will create a network interface for UDP/IP, modify its PC based data logger for UDP/IP, create tools to perform DIS <-> SIMNET conversion (by aligning data structures and bridging misaligned or non-aligned elements), and modify its Computer Generated Forces Testbed to be compatible with UDP/IP (5/6/92).

Based on developments at IST (reported previously), IST feels confident about supporting a UDP/IP and Ethernet implementation for the demonstration. The specific UDP/IP features to be utilized are currently being investigated by IST. IST will also continue to investigate performance related issues of UDP/IP. As issues arise, they will be reported under separate ACTION ITEMS/DECISIONS.

The following paper represents IST's assumptions regarding UDP/IP (5/14/92):

UDP/IP Requirements and Specifications
for
I/ITSC Interoperability Participants

Participants will be given their IP addresses on arrival at I/ITSC. Those having multiple machines will be accommodated. IST requests that all participants having multiple machines connect each machine directly to the showroom LAN. Because addresses will not be available until I/ITSC the participants are expected to be able to configure their machines at that time.

As of this writing (May 14, 1992) the LAN protocol is still open. We expect to resolve this by selecting Ethernet or 802.3 at the May 19 meeting at IST (Ethernet has been selected (6/23/92).

If any inter-participant messages must be put on the LAN during demonstrations they should be point-to-point if possible and, if that is not possible, multicast. Broadcasted inter-participant traffic should be avoided if at all possible.

Legitimate simulation traffic, and only such traffic, is to be directed to UDP port 3000 (decimal) using IP broadcast. IST emphasizes that Inter-participant traffic, unless point to point, does not use this port. For inter-participant traffic, other than standard Unix services (defined in RFC 1060 -- Assigned numbers), participants should allow port configuration. At I/ITSC IST recommends participants use ports 3xxx, with xxx matching one of their IP host addresses.

IST makes no recommendations for the UDP source port (the UDP source port is defined, in RFC 768 - User Datagram Protocol, as an optional field). IST also makes no recommendation as to whether the UDP optional checksum is computed or is sent as zero (see RFC 768).

Since simulation PDUs do not require IP fragmentation, there should be no fragmented IP traffic to UDP port 3000. Because all simulation packets are broadcast, no ARP requests are expected relating to the simulation proper. Participants may choose to ignore ARP requests and ICMP packets and participants are not required to generate either.

The following represents information concerning the physical network to support the I/ITSC Demonstration:

IST has prepared a detailed network layout for I/ITSC and is coordinating with the I/ITSC facilities group regarding cable layout. Gamini Bulumulle at IST has copies of the layout. Thin coaxial will be the physical connection used in the I/ITSC demo (5/19/92). IST will supply the cable, repeaters and T-connections for the I/ITSC demonstration (6/23/92). IST has received information from Motorola regarding wireless ethernet. As the participants are identified, IST will evaluate this system for

suitability for I/ITSC (4/22/92). A decision was reached (5/19/92) not to use a wireless LAN for the I/ITSC demonstration. This decision was based upon a study and recommendation by IST. IST has determined that the time required for tuning the system for the unique showroom configuration may be excessive. Tuning could be required for dead zones, to reduce overlapping coverage areas, and to account for EMI from other simulators. Vendors wishing to use wireless Ethernet can use the IST provided backbone to demonstrate performance (5/6/92). The Physical Layer protocol will be Ethernet not IEEE 802.3 (CSMA/CD).

This closes ACTION items 2, 4, 7, 19, 29, 30, and 31.

DECISION 22: The next meeting (third) on the I/ITSC demo will be held on June 23, 1992 at IST (5/19/92).

DECISION 23: A tutorial on SIF will be held on June 24, 1992 at IST (5/19/92).

DECISION 24: No new icon models will be allowed after June 23, 1992. (6/23/92) IST has received a complete list of models. The degree of articulation required will be requested of participants (Shen) (5/11/92) by 5/19/92. No weapon attachments to the entities as articulated parameters will be used (5/19/92). David Shen/IST will provide all participants a list of entity models and their providers by June 5th. This closes ACTION item 5.

DECISION 25: Interactive testing will be conducted using 1-800 dial up lines, no 56kbps service. The reason is that to date, no organization has indicated a willingness to fund new 56kb service at their organization. Therefore, interactive checkout of interoperability is limited to commercial telephone service. This decision limits the number of entities which can simultaneously experiment with interactive simulation prior to I/ITSC. IST intends
to install two lines with 800 service (date currently unknown) and use 9600 baud modems for interactive networking experimentation. The scenarios for I/ITSC will be developed in a tiered approach where the number of participants can grow if the network can support the number of entities desired. Experimentation can occur during off hours at I/ITSC (5/11/92). This closes ACTION items 8 and 34. (6/23/92)

DECISION 26: All testing will be conducted by IST, no third party testing will be required. (6/23/92)

DECISION 27: To ensure a win-win scenario, all participants will be on the same side (friendly) and will fight SAF (foe) generated by IDA, BBN, and IST. The SAF will be "targets" with limited fighting capability. (6/23/92)

DECISION 28: Two formal exercises will be conducted at I/ITSC: Monday morning during the opening plenary and Tuesday night before the banquet. An informal exercise to test experimental PDUs (e.g., Emitter PDU) will take place on Wednesday morning. (6/23/92)

DECISION 29: IST will prepare and maintain a list of Action Items and Decisions. This closes Action 1. (4/22/92)

DECISION 30: Testing results of individual companies will be kept confidential. (6/23/92)

DECISION 31: IST will assign site and host id numbers before I/ITSC so that participants can make the appropriate changes to their simulator software. (6/23/92)

DECISION 32: IST will generate a SAF helicopter and a carrier for the formal exercises. (6/23/92)

DECISION 33: Coordinates will be expressed using WGS 84. Numerous papers and opinions have been expressed concerning the use of a non-flat earth. Potential problems include differences in simulated position versus position in the visual system as well as accumulated roundoff and truncation errors. IST will develop an algorithm (after obtaining a group of algorithms from TEC) for converting from various flat earth representations to WGS 84. Brian Goldiez has the most complete set of papers on issues, concerns and algorithms related to this topic. See ACTION item 24 (6/23/92).

DECISION 34: The next meeting will be held at IST on July 29, 1992 starting at 9:00am. (6/23/92)

DECISION 35: IST (David Shen) has created a list of model types in accordance with the DIS standard. This list also identifies the degree of articulation for specific model types. This completes ACTION item 6. (6/23/92)

DECISION 36: IST will create a Test Procedures to determine simulator compliance with the portions of DIS applicable to the I/ITSC demonstration. See ACTION 21 (7/10/92).

The first draft of the test procedures will be released early during the week of 16 June 1992 (6/4/92).

Test Procedures have been released. They will be finalized by IST before the July 29 meeting. Finalization will include coordination with participating organizations, establishing criteria, and additional technical details. Coordination will ensure that each participant is comfortable with the scope of testing. Participants can recommend the addition or deletion of specific tests. Criteria will help establish acceptable ranges for cumulative tests. This will assist participants in addressing and prioritizing success or failure of particular tests. Criteria will also help establish minimum criteria for participation in various

types of I/ITSC demonstrations. Additional technical detail will include interactive testing (limited scenario development), the creation of tolerances for values (e.g., coordinate transform positional and angular tolerances), network stress testing (through disks distributed to participants, or the use of the IST SAF, or through some form of interactive testing). (6/23/92).

The second draft of the Test Procedures, dated 7/10/92 will be released during the week of 7/13/92 (7/10/92).

DECISION 37: A compromise was reached that was satisfactory to all visual vendors. Within a 300 square kilometer area several ground rules will apply. First, participants are requested to use the polygonal 2851 SIF format to match polygon dimensions to within one meter. Secondly, the 300 square kilometer area will be the only area where ground forces will be present and the only area where ordnance may be delivered to the ground. Within the other 9700 square kilometer area vendors may use either the gridded or polygonal representation of terrain. (Lower left is FQ 5073, upper left is FQ 5083, lower right is FQ 8073, and the upper right is FQ 8083). (7/29/92)
STATUS: OPEN. (8/20/92)

DECISION 38: The following was the agreement reached regarding ground rules for participating on the network at I/ITSC. IST (Margaret Loper) will develop a detailed plan to bring the network online and bring participants onto the network. Participants who take part in the integration and testing activities in San Antonio starting on October 26 will receive priority in integrating their systems at I/ITSC. There is a 30 hour window between the time when the Exhibit Hall opens and when the Plenary session starts. The time is to be allocated as follows:

FIRST TEN HOURS. The network will be configured and participants will set up their equipment and establish a network capability similar to the capability established during the week of October 26. This time could be expanded (but will be less than 20 hours) if setup or reconfiguration difficulties are encountered.

SECOND TEN HOURS. Participants unable to take part in the activities of October 26 will be afforded an opportunity to get on the network. The baseline network established, above, will not be compromised. That is, if someone is unable to get on the network (with sufficient help from participants) or causes other problems which impact other participants; that participant's simulator will be rejected for participation and the participant will be put into the bottom of the queue. Each participant will be given a one hour block to establish connection to the network. It is possible that the baseline network established in the first ten hour period may be broken into sub-nets if there are more than 2

organizations needing to get onto the network. A lottery will be held by IST if there are more than 2 organizations needing to get on the network during this time period.

A participant will be denied access to the network for the Plenary Demonstration if they are unable to connect to the network or they adversely affect other simulators on the network.

PLEASE NOTE: There is a chance this time period could be greater than or less than 10 hours. Past experience indicates a small probability that the time period will be greater than 10 hours.

THIRD TEN HOURS. This period will be devoted to rehearsal and fine tuning of the Plenary demonstration.

If an organization, not participating in the October 26 integration period, is unable to participate in the Plenary Demonstration, they will be afforded an opportunity to establish a network connection and not adversely affect other simulators on the network during the course of the I/ITSC. This activity will occur on a non-interference basis with other network activities. IST will provide reasonable support. Connection without adverse impact will be required for the demonstration to be conducted at the Cocktail hour on Tuesday evening.

Dan Mullally strongly suggested that companies that cannot attend the rehearsal send an observer so that they can "catch up" with those all ready there. Hand walkie-talkies will not be practical for simulator operators. Dan Mullally will talk to the contractor about the possibility of headsets or some other type of communication system. Maps were mailed on the 10th of August. Detailed plenary and banquet scenarios will be available on Oct. 26. Free play will be allowed during rehearsals. A list of items that will be used as targets is needed from each participant. The Stealth screen should be up for free play (8/20/92).

DECISION 39: The next meeting is scheduled to be held on Wed. 23 Sept. 92 during the evening at the scheduled DIS workshop at the Holiday Inn on International Drive in Orlando (8/20/92).

DECISION 40: The network is **public**. All participants can tap the network to collect data (8/20/92).

DECISION 41: IST will provide only one Ethernet BNC interface per booth (see DECISION 21) (8/20/92).

DECISION 42: Relative time stamps will be used for PDU's on the IITSC network. This decision was made several months ago, but was not recorded (10/8/92).

ACTIONS

ACTION 1: Create list of Action Item's & decisions & send out (4/10/92).
STATUS: COMPLETE. See Decision 29. (4/22/92)

ACTION 2: Investigate wireless E-NET (Ralph Whitney get data to IST) (4/10/92).
STATUS: COMPLETE See Decision 21. (5/6/92)

ACTION 3: Identify participants for the I/ITSC Demonstration by 4/17 (4/10/92).
STATUS: IST has identified the following organizations who will participate in the demo:

LORAL - John Russell/(408)473-7351
IST - Mikel Petty/(407)658-5023
TSI - Chuck Benton/(207)882-7589
CAE-LINK - Sam Knight/(607)721-4602
NTSC - David Kotick/(407)380-4606
BBN - Richard Schaffer/(617)873-3317

Several other organizations are awaiting management approval. (4/22/92). Additional organizations now include:

HUGHES - Mike Robkin/(818)915-9788
ARMSTRONG LABS. - Brian Rogers/(602)988-6561
IDA - Chris Turrell/(703)845-6832
GENERAL ELECTRIC - Tim Hanes/(407)473-7036
(5/11/92).

Additional organizations now include:

Lockheed-Sanders - Dan Bradford/(603)885-9863
Grumman - Ken Doris/(516)224-6108
IBM - J. Joseph Brann/(703)367-2738
(5/15/92).
Reflectone - John O'Reilly/(813)885-7481 X3051
Star Technologies - Dave Wilson/(919)361-3835
Motorola - Ralph Whitney/(407)823-7000
(6/23/92)
NRaD - Marc Poris/(619)553-6149
(6/29/92)
Gen. Dynamics Land Systems - Alan Aouate/(313)825-7977
Gen. Dynamics, Ft. Worth Div. - Mat Landry/(817) 777-2872
(7/8/92)
Concurrent Computer - Malcolm Bell/(407)851-4480

Additional Organizations now include (10/13/92)

STRICOM - Karen Danisas/(407)381-8693
USAF ASD - Jim Bassinger/(513)255-7184
DMSO - Col. Ed Fitzsimmons/(703)998-0660
Silicon Graphics (MAK) - Afshad Mistri (Warren Katz)/(415)390-1270 ((617)876-8085
PRC - Gene Clayton/(703)556-1480
McDonnell Dougals Training Systems - Dave

Coblitz/(314)895-0995
Rockwell International Space Systems Div - Randy Baker/(310)797-4777

ACTION 4: Select physical n/w layer (4/10/92).
STATUS: COMPLETE. See Decision 21. (5/19/92)

ACTION 5: Notify IST of all new models needed by April 30. Conversion of new models will begin June 1 at IST (Curt Lisle). IST will convert models on a first come, first serve basis, subject to resource availability (4/10/92).
STATUS: COMPLETE. See Decision 24. (6/23/92)

ACTION 6:"Model form" to be generated by IST and distributed to group next week. Due back to IST by end of month (model - # articulated parts - weapons/munitions). A description of articulated parts, including their connectivity will be supplied by the organization providing the model data (4/10/92).
STATUS: COMPLETE. See Decision 35. (6/23/92)

ACTION 7: Rules(4/10/92)
-IST will assess the feasibility of implementing UDP/IP with the help of NTSC
- NTSC will not distribute test streams (if they have to generate them) - IST will distribute
- Protocol translator (C. Benton)
  turned on: May 1
  delivered: July 31
  - $8K board with sw modules
  - SIMNET - DIS (now)
  - SIMNET/Association - DIS/UDP-IP (future)

STATUS: COMPLETE. See Decision 21. (5/19/92)

ACTION 8: Companies must indicate their network bandwidth needs for testing willingness to pay for 56kb lines on their end (Contact Margaret Loper). This information is to be provided no later than 4/17 (4/10/92).
STATUS: CLOSED. See DECISION 25. (6/23/92)

ACTION 9: Richard Schaffer (BBN) will provide IST with S1000 and MCC compiled software of new terrain database (4/10/92).
STATUS: COMPLETE (5/17/92).

ACTION 10: Motorola and Margaret Loper will determine BW capabilities on show floor net (4/10/92).
STATUS: Current activity has uncovered several parameters which will influence bandwidth on the show floor. First, is 10 Mbs from Ethernet. Ethernet is not expected to be the limiting factor. Second is any interface hardware between the network and the host computer. Third is particular implementation of UDP/IP. Experience from some companies indicated a 200-300 packet per second rate on Sun's UDP/IP. Fourth is the simulator math model limitations on tracking moving models or other DIS related

parameters. Fifth is the visual system limitations on dynamic coordinate sets or other DIS related parameters. Sixth is the limitation noted elsewhere on interactive testing using commercial telephone linkage and 9600 baud modems. IST is investigating each aspect noted above to arrive at limiting factors for demonstrating DIS (5/11/92). Margaret Loper presented updated results 6/23/92. The results follow:

In order to complete the BW analysis, a questionnaire (see ACTION 33) was distributed to participants surveying simulator processing capabilities. Participants were asked to identify the following processing constraints: interface hardware (in PDUs/sec), communication protocols (in PDUs/sec), simulator math models (in # of entities), and IGs (in # of dynamic coordinate systems). The following ranges were obtained:

```
+------------------------+
|      IG Filtering      |          6 - 800 entities
+------------------------+
            ^
            |
+------------------------+
| Simulator Math Models  |          6 - 800 entities
+------------------------+
            ^
            |
+------------------------+
|      Communication     |
|   Protocols (UDP/IP)   |          15 - 500 PDUs/sec
+------------------------+     * not all participants responded to
                               this question
            ^
            |
+------------------------+
|   Interface Hardware   |          30 - 2000 PDUs/sec
+------------------------+
            ^
            |
-----------------------------------------------------------------
--
                         Ethernet  (10Mb/s)
```

From the BW program developed by Grumman, the following data was calculated:

Entity Type and Number	->	100 tanks, 11 aircraft, 1 ship
Low Rate (no conflict)	->	55 kbps or 22 PDUs/sec
High Rate (all conflict)	->	800 kbps or 311 PDUs/sec

From initial calculations we can make the following assertions:

1) 112 entities will not exceed Ethernet (10Mbps).
2) The interface hardware and UDP/IP processing constraints will present the biggest problem in determining the number of entities participating in the demo. The trade-off is low-performance vs. high-performance simulators. Scenario development will not solve this problem.
3) Simulator math models and IG constraints will be secondary problems and may be alleviated through filtering and prioritization. If not, scenario development can strategically place entities so as to pre-filter for those simulators not capable.
4) If all entities are in low or no conflict, minimal problems should occur at simulator hosts.
5) If all entities are in high conflict, major problems will occur with low-performance simulators. A rate of 311 PDUs/sec will overwhelm the lower bounds of 30 and 15 PDUs/sec for hw interface and UDP/IP, respectively.

(6/29/92).
ACTION 11: IST will get polygon models from NPS. All models for this demonstration will be distributed by IST or PRC (4/10/92).
STATUS: COMPLETE. See DECISION 7. (6/23/92)

ACTION 12: IST will produce a matrix of weapon/munition vs. platform and assign probability of kills. We will distribute next month (May). **((See SIMNET vehicle simulator documents because some are all ready done)) (4/10/92)
STATUS: COMPLETE. See DECISION 13 (5/30/92).

ACTION 12A: IST offered to produce a DIS version of the ISF testbed which used BBN's AP or else straight IEEE-802.3 frames. IST promised to look into implementing a minimal UDP/IP interface for the testbed. No firm dates were specified (4/10/92).
STATUS: CLOSED. IST will implement UDP/IP (4/27/92). Item was modified to 12A to avoid duplication with other Action Item 12 (5/30/92). See DECISION 21 (6/23/92).

ACTION 13: IST will assess the number of entities which can be simultaneously demonstrated at I/ITSC. Limits will be based upon the lesser number of CIG moving models, network bandwidth, or simulator limitations (4/10/92).
STATUS: CLOSED. This matter is covered in Action Item 10.

ACTION 14: There is a need for IST to check the draft standard to see if the entity codes that have been provided in Appendix H2 will support the selected models. IST will define numbers for undefined entities (4/10/92).
STATUS: CLOSED. DECISION 24 closes this item (6/23/92). As items are submitted, they are checked for Appendix H2 coverage. Those items which are not covered are assigned an entity code (5/6/92).

ACTION 15: PRC will get SIF format or ASCII format to the rest of the group by July 15. If IST is overloaded, participants will be responsible to get SIF or ASCII format to the rest of the participants by 15 July (4/10/92). Modify this Action Item to read, "Regarding moving models, PRC will get SIF format to the rest of the group by July 15. If IST is overloaded, participants will be responsible to get SIF or ASCII formats to the rest of participants by July 15. If PRC receives an ASCII model, they will provide it to IST "as is". The entire Terrain Data Base will be available August 15" (4/15/92). A SIF sample has been prepared and is available. The Hunter Liggett area is currently being validated by PRC. The validation will not be completed until the latter part of August. Therefore, distribution of the 2851 SIF data base of Hunter Liggett will not occur until the end of August. The period for testing will be reduced to September and October due to data base delays and the need for participants to tailor the testing document (7/29/92). PRC has made distribution of and updates to SIF format. Algorithms for map conversions were distributed by Huat Ng. A decision was made to freeze the current version of the database, due out during the week of 25 Sept. 1992 (9/23/92).
STATUS: CLOSED. (9/23/92)

ACTION 16: Chuck Benton (TSI) and Loral are to get back to IST by 17 April concerning the use of the PDU translator to do testing of DIS at IST using the SIMNET equipment in the IST lab (4/10/92).
STATUS: CLOSED. Translator does not currently support UDP/IP. Currently reviewing necessary effort to accommodate UDP/IP. (4/22/92)

ACTION 17: Neale Cosby, for IDA, will work with IST on integrating scenario generation with testing in the schedule. IDA will supply large screen display and display driver from network for I/ITSC (4/10/92). Final floor plan and layout info not available (7/29/92). Neale cosby discussed set-up of large screen display. IDA will provide access and availability schedule on a sign-up basis during the open time. Margaret Loper has openings in the sign-up sheet for informal (freeplay) exercises (see ACTION 37). Openings for freeplay exercises are still available (9/23/92).
STATUS: OPEN (9/23/92).

ACTION 18: For display of damaged appearance, model developers (PRC or IST) will need to develop damaged version of various vehicles (4/10/92).
STATUS: CLOSED. See DECISION 7 (6/23/92).

ACTION 19: IST (M. Craft) will create a list of assumptions for participants regarding the use of UDP/IP for the 5/19 meeting (5/6/92).
STATUS: CLOSED. See DECISION 21 (6/5/92).

ACTION 20: IST (Goldiez) will arrange a colloquium for parties interested in learning more about UDP/IP (5/6/92). A UDP/IP colloquium will be held on August 21 for 2 hours in the morning. More info will be sent out at a later date. Contact Michael Craft (7/29/92). The UDP/IP colloquium was filled to capacity. This completes ACTION 20.
STATUS: CLOSED (8/20/92).

ACTION 21: IST will determine and announce the date of completion on test procedures by June 5th (5/19/92).(7/29/92).
STATUS: CLOSED. See DECISION 36 (7/10/92).

ACTION 22: IST will accumulate and analyze network traffic collected during the I/ITSC demo (5/19/92). Gamini Bulumulle discussed the capabilities of the network analyzer (8/20/92). Analysis of the network will be made during and after I/ITSC (9/23/92).
STATUS: OPEN (9/23/92)

ACTION 23: IST will provide and distribute a hit/kill matrix by weapon/target by the end of May. This matrix will be used for kill probability determination for use in the I/ITSC demo (5/19/92).
STATUS: CLOSED. See DECISION 13.

ACTION 24: Participants should return comments regarding geocentricity paper by Brian Goldiez by June 5th (5/19/92).
STATUS: IST will develop the algorithms for coordinate transformations and present them to the group and to TEC. See DECISION 33 (6/23/92). IST presented its analysis and recommendation for coordinate transformation algorithms between geocentric, geodetic, and topocentric coordinate systems. A method using Newton-Raphson's algorithm was suggested. The methodology and rationale is described in IST-TR-92-24 entitled "Interconversions Between Different Coordinate Systems", dated July 1992. IST asked that the algorithms recommended in this report be approved for use in describing coordinate transformations. I/ITSC

participants were given until August 12, 1992 to comment on the algorithm recommendation. If no comments are received, or are properly dispositioned, the Newton-Raphson algorithms will be used (7/29/92). Discussions on geocentric coordinate system remains open (9/23/92).
STATUS: OPEN. (9/23/92)

ACTION 25: IST will find guidelines for videotaping for individual companies (5/19/92). Neale Cosby (IDA) spoke on the value of video-taping. Demo players were asked to respond by 9/15/92 on each company providing 3-5 minutes on 3/4" or 1/2" tape. This will be used as a DIS promo (8/20/92). During a discussion on video-taping of the DIS demo, the U.S. Army, STRICOM (Stan Goodman) announced the decision to support the cost to videotape during I/ITSC. The demonstrators would have access to review the tapes (9/23/92).
STATUS: OPEN. (9/23/92)

ACTION 26: IST will provide models through Internet when available (5/19/92).
STATUS: Pending return of models from PRC (6/1/92).

ACTION 27: IST will provide information regarding special effects visualization, i.e. muzzle flash, explosion, etc..
STATUS: COMPLETE. See DECISION 7 (6/23/92).

ACTION 28: A list of minimum hardware specifications must be provided to all participants for the IST developed SAF (5/19/92). IST provided specifications to all who attended the demo meeting on 5/19/92. Loral (ADST contractor) distributed the IST developed SAF to all I/ITSC demo players (see ACTION 49) (8/20/92).
STATUS: CLOSED (8/20/92).

ACTION 29: Participants will decide on using either Ethernet or 802.3 and return decision to IST no later than June 5, 1992 (5/19/92).
STATUS: CLOSED. See Decision 21. (6/23/92)

ACTION 30: IST will provide cables, repeaters, and T-connections for the demonstration (5/19/92).
STATUS: COMPLETE. See Decision 21 (6/23/92).

ACTION 31: IST will provide a detailed network layout (5/19/92).
STATUS: COMPLETE. See Decision 21 (6/23/92).

ACTION 32: A request was made by Dan Mullally/IST to develop and return by June 5, 1992 the scenario outlines provided at the 5/19/92 I/ITSC demo meeting (5/19/92).
STATUS: Detailed sample scenarios will be created by IST by July 15, 1992. The scenarios will separately support testing and the I/ITSC demonstration. (6/23/92). A demonstration vue-graph outline form was presented to all participants to complete and

return. Time constraints during the pre-banquet demo will require that the scenarios be shortened to allow concurrent land, sea, and air play. Detailed scenario information will be distributed to all participants A.S.A.P. (7/29/92). Detailed scenarios will be created based on the outlines previously distributed (8/20/92). Draft plenary and banquet demonstration scenarios were distributed for review. Attendees were broken up into air, land, and sea sub-groups to review and provide input to modify the draft scenarios. Attendees were asked to submit individual and sub-group recommendations for modifications (9/23/92).
STATUS: OPEN. (9/23/92)

ACTION 33: Margaret Loper will prepare and distribute an entity survey form to determine network bandwidth equipment. Forms should be returned to IST no later than June 1, 1992. Forms faxed 5/20/92. She will present at the next demo meeting scheduled for June 23, 1992 (5/19/92). The surveys completed by participants indicate a maximum of 235 entities can be generated by the participating simulators. However, the Physical interface hardware and UDP/IP processing constraints will limit the number of entities that can actually participate. This analysis is on-going under ACTION 10 (6/23/92). Analysis is ongoing. Margaret Loper could identify the upper bounds but could give no information on specific scenarios (7/29/92). Analysis continues in view of the changing players and scenarios (9/23/92).
STATUS: OPEN. (9/23/92)

ACTION 34: IST will investigate fractional 56 kbps lines and provide information at the next meeting on the I/ITSC demo (5/19/92).
STATUS: CLOSED. See DECISION 25. (6/23/92)

ACTION 36: IST will place an announcement about the I/ITSC demo in the CBD. (6/23/92) CBD announcement request passed to STRICOM for action.
STATUS: CLOSED. (7/29/92)

ACTION 37: Margaret Loper will generate a schedule of formal and informal exercises for participants. A sign-up sheet for scheduling informal (including freeplay) exercises will be developed and distributed to participants by July 1. Responses are due back by July 15 (6/23/92). Free play time slots are still open (7/29/92). A list of items that will be used for targets is needed from each participant. Free play will be allowed between all demo players on a sign-up basis. IDA will make the large screen available during these freeplay exercises.

IST will develop specific uses and demonstrations for the network at I/ITSC. IST will then attempt to get participants involved in utilizing the network. Only when participants have indicated interest in utilizing the network (either with IST or separately) will IST attempt to assist in defining experiments (8/20/92). A discussion on the availability of the large screen

for freeplay demonstrations was held. Availability will be determined through coordination with the I/ITSC special events committee by Bruce McDonald, IST. Time slots for demos are still available (9/23/92).
STATUS: OPEN. (9/23/92)

ACTION 38: Traffic on the network is divided into two types: DIS PDUs, which all participants must accept and respond to and Other Data, which participants should expect to see but require no response. Margaret Loper will send a questionnaire asking participants to define the Other data they expect to put on the net (e.g., Emitter PDU) by July 1. Responses are due back by July 15. A composite list of DIS and Other data will be sent to participants by July 24 (6/23/92). Action remains open due to limited responses to the survey (7/29/92). (9/23/92).
STATUS: OPEN. (9/23/92)

ACTION 39: IST will investigate integrating the SLIP protocols into the ISF testbed. (6/23/92)

There are three methods to allow connection to IST for testing. One is to use lease lines (T-1 with CSU/DSU). A second method is to use routers and the third method is to use SLIP (Serial Line IP) or PPP (Point to Point Protocol). Lease lines are not cost effective for IST and the lead time for procurement and installation makes them impractical. Routers are not practical because their internal data conversion routines are proprietary. Therefore, if one uses a router, they must have the same router on each end of the connection. Such an arrangement is not practical or cost effective for this demonstration.

The third method is to use interface software to support testing. SLIP is available at no additional cost on several computer systems (e.g., SUN). SLIP as a stand alone product (e.g., DOS version) is available for purchase. PPP is a new product with higher performance than SLIP. However, the availability of PPP is currently limited to DOS machines (7/27/92).

IST received the necessary hardware (NetBlazer, 2 modems) and is in the process of networking with the Sun and Motorola networks. At the same time IST is trying to install SLIP software (DOS version) in a PC and connect it to the network using a serial line (RS232) (7/16/92). Based on the June 1992 Interoperability meeting at IST, the third method (interface software) will be used for the I/ITSC demonstration and the DIS testbed at IST. The hardware configuration at IST will support SLIP or PPP. IST will demonstrate the use of SLIP and most of the testing set-up on 7/29/92.
STATUS: CLOSED. (7/29/92)

ACTION 40: IST will look into the price difference and vendor interoperability of 9.6 and 19.2 modems (6/23/92).

Vendor interoperability requirements: Any modem which is fully compatible with the CCITT V.32 specifications.

Price difference : Most of the asynchronous modems runs from 300bps to 38.4kbps. The modems listed below can accomodate our 19.2kbps requirements.

TELEBIT T3000 modem - $645.00 (used in our application).

Motorola V.3225 Data Modem - $574.00

Black Box has various types of modems.

Modem 3242-XB - $795.00
Modem 32144 - $1395.00
STATUS: CLOSED. (8/20/92)

ACTION 41: IST will look into the price difference and vendor interoperability of 9.6 and 19.2 modems (6/23/92). Gamini Bulumulle announced the v.32 standard, price difference and vendor interoperability of the 9.6 and 19.2 modems.
STATUS: CLOSED. (7/29/92)

ACTION 42: IST will identify the location of walkie-talkies in all booths (6/23/92). Action remains open until all booth locations and participants are identified (7/29/92). A walkie-talkie will be assigned to each demo player booth. Martin Marietta (Bob McCauley) has 12 voice activated radios available (8/20/92). Action remains open (9/23/92).
STATUS: OPEN. (9/23/92)

ACTION 43: Brian Goldiez will distribute a questionnaire on detailed simulator configurations by July 6. Responses from participants are due back by July 31. (6/23/92) Questionnaire will be distributed during the week of 7/13/92 (7/10/92). Detailed simulator configuration data is still pending from several demo players. All players were asked to complete and return data required, A.S.A.P. (8/20/92). (9/23/92).
STATUS: OPEN. (9/23/92)

ACTION 44: IST will develop a list of POC's from each company participating in the I/ITSC demo. Brian asked all demo participants to provide him with a written statement of intent to participate in the I/ITSC demo (7/29/92).
STATUS: COMPLETE. (8/20/92)

ACTION 45: A decision was made to determine if a space could be found in San Antonio, TX for a rehearsal by all participants in the week preceding I/ITSC. All participants were asked to provide space, power, cooling and weight of their equipment.

Arrangement to have equipment moved by USAF from rehearsal site to the convention center was also discussed. The USAF (Capt. Johnson) will act as a POC to determine the availability of a rehearsal site in San Antonio during the week preceding I/ITSC (7/29/92). Space options were discussed with the option of a separate room in the convention center being the preference of all demo players.

Requirements (size, weight, power, # of outlets); must have this info. to find adequate rehearsal site. If unsure, give estimate of worst possible case (i.e., maximum power, largest size, etc.). Want rehearsal to be up and running Wed., Oct. 26.
A lengthy discussion followed during which the benefit of having a rehearsal was debated. A way to prioritize those individuals who attend the rehearsal and those who do not was discussed.

Brian Goldiez went over the decided method for rehearsal and testing:
One week before I/ITSC (Monday, Oct. 26), a facility previously secured for rehearsal and testing will be available to the participants. The first choice would be a place in the convention center (to minimize the move to the exhibition hall). A second choice would be a military facility close to the exhibition site.

Dennis Shockley is investigating the feasibility of using the convention facility (not the actual exhibit hall) starting on October 26. Dennis is also investigating funds necessary to secure the facility if it is available. This action should be dispositioned by 8/28.

IST (Bruce McDonald) should work with JMK to ensure I/ITSC participants receive priority on moving our equipment into the Exhibit hall. JMK should be invited to attend the next meeting in September.

The companies that show up for rehearsal will be tested one at a time and then matched up in groups. The testing will make sure that certain programs do not "crash" the network and will help the companies work out the "bugs" in their systems. Each company must bring enough equipment so as to adequately represent the simulations they will be presenting in the regular conference. On Saturday, all those companies that are in rehearsal must be prepared to disconnect and move to the exhibition hall. The first ten hours will accommodate the rehearsal companies and establish connectivity. The second ten hour period will be for those companies who could not be there for rehearsal to see if they can get on the network without problems. If they cannot get on the network, they cannot participate in the plenary. The third ten hour period will be used for rehearsal and "fine tuning" for those participating in the plenary (8/20/92). A briefing and update on the demonstration times and locations was given by Dan Mullally and Mr. Keith Tanner of JMK associates:

a. Rehearsal location. The I/ITSC Facilities Cmte. has secured the use of the Gallery Room in the San Antonio Convention Center. The Gallery Room has space for the demo players to set-up their minimum equipment configuration for the demo rehearsal.

b. Time of Arrival. The contractor will be prepared to handle heavy lifts on Monday 26 October 1992 from 0800 to 1100. A heavy lift is anything requiring a fork lift that cannot be hand carried or placed on a dolly. Time of delivery of heavy lifts after Monday can't be guaranteed by the convention contractor due to another show scheduled into the San Antonio Convention Center. The contractor will charge for the heavy lift movement.

c. Power Requirements. A new electrical contractor has been engaged for the San Antonio I/ITSC convention. Forms for the electrical contractor (Harper -Wood) will be available at the 23 Sept. DIS Workshop meeting of the Demo Participants at the Holiday Inn, International Drive here in Orlando.

d. Rehearsal floor plan set-up: The set-up will be based on the actual I/ITSC South Exhibit Hall floor plan to be used during the 2-5 Nov I/ITSC. Gamini will provide tentative network floor plans at the 23 Sept meeting. Gamini will set up ethernet network and individual spaces based on the sq. ft. requirements previously submitted.

e. Rehearsal Schedule:

Monday, 26Oct92: Arrive at Convention Center and set up rehearsal area in Gallery Room. Access for all hand carried and dolly cart carried equipment available from S. Alamo St. entrance. Electrical contractor on-site to provide pre-arranged power. Network Tests start as soon as possible.

Tuesday, 27Oct92: Network Tests continue. Appearance Tests and Scenario Testing will be scheduled ASAP based on Network test status.

Wednesday, 28Oct92: Rehearsal continues.

Thursday, 29Oct92: Rehearsal continues.

Friday, 30Oct92: Rehearsal continues. Lila Cockrell Theatre in the Convention Center available from Friday Morning for set-up. Friday Noon, South Exhibit Hall available for Booth set-up by rehearsal players.

Saturday, 31Oct92: 0900-1300 ethernet will be laid out in South Exhibit Hall. Network Re-test begins at 1300.

Sunday, 1Nov92: Rehearsal continues. Exhibits open 1700-2000.

Monday, 2Nov92: Rehearsal continues. Interoperability Demo for Plenary session scheduled at 0930.

Tuesday, 2Nov92: Exhibit Hall opens 0900. Freeplay Demonstrations 1100-1800, Banquet Demonstration 1900-1920.

Wednesday, 4Nov92: Freeplay Demonstrations 0900-1200. Exhibit Hall Closes 1200.

At the DIS Demo meeting on 23 September all demo players were asked to provide final electrical, telephone, and heavy lift requirements to the Convention Contractor. The contractor will ask for the weight and cube of the heavy lift (Fork Lift) requirements.

Draft Final Scenarios will be presented at the 23 September Meeting. Please contact me at (407) 658 5023 voice, 5059 FAX on any networked simulator changes which will affect the scenarios (9/23/92).
STATUS: CLOSED. (9/23/92)

ACTION 46: A discussion on separating the initial presentation into an overview given by an Air Force general and a more specific briefing given by an appropriate presenter using canned or video augmented presentation along with live scenario play was held. Dan Mullally will report at the next scheduled meeting on this item (7/29/92). The plenary demonstration and presentation will be given by Lt.Gen. Rogers, J-7, interoperability (8/20/92).
STATUS: CLOSED. (8/20/92)

ACTION 47: A request to provide military maps to all participants of the Hunter Liggett area is being looked into by Dan Mullally (7/29/92). Simnet maps of the Hunter-Liggett area were distributed to all players on 8/20/92. Additional 1:50,000 tactical maps of the Hunter-Liggett have been requested from the Army and will be distributed when received (8/20/92). A decision was made that the Army, STRICOM (Stan Goodman) would provide maps to all participants (9/23/92).
STATUS: OPEN. (9/23/92)

ACTION 48: Visual system data bases were discussed during the (7/29/92) meeting. Ken Oda explained the formats being provided for P2851 SIF. Ken explained that the source of the Hunter Liggett gaming area for I/ITSC is the BBN data base used in SIMNET. The data processed into 2851 SIF using a formatter that converts from the BBN S1000 modeling system to a 2851 format. The resulting SIF is converted from UTM to Geodetic and is also formatted to be consistent with the 2851 specification. Ken Oda will provide participants with the algorithm used to convert from UTM to Geodetic. Ken also agreed to look into the possibility of PRC generating maps from the data base and report to the group at the next meeting on this possibility. Two forms of SIF will be provided; a polygonal representation and a gridded model.

There was quite a bit of discussion on which version one should try to match. The non-BBN vendors had concerns about using the polygonal model as a baseline to match their own terrain models. The reasons for the concern were the lack of specific vendor tools for converting someone else's (including 2851) polygonal models to a data base compatible with the vendors image generator, the amount of time and money necessary to make the conversion, and the performance implications of using a data base which was originally optimized and derived from a specific system (i.e., BBN) which is different from everyone else's system. It should be noted, in defense of BBN, that this problem would arise if any other vendor's data base was used as a source.

Ken Oda will provide algorithms and maps of the terrain data base (7/29/92). Ken Oda reported that the culture data base was not ready yet. The complete data base will be ready next week. Ken Oda will provide map and conversion algorithms (UTM to geodetic) (8/20/92).
STATUS: OPEN. (8/20/92)

ACTION 49: The IST CGF System will be present in the I/ITSC Interop Demo in three different roles.
(1) in support of pre-I/ITSC testing
(2) as support at the I/ITSC demonstration
(3) as an active participant in one or more of the I/ITSC scenarios

STATUS: A minimum CGF workstation consists of two IBM-compatible 386 or 486 PCs. One of the PCs runs the entity simulations (the 'Simulator') and the other provides an operator interface (the 'OI'). Additional Simulators or OIs may be added to the configuration as needed. Both the Simulator and OI are connected to the ethernet network, and they communicate with each other over the network, exchanging non-standard PDUs. The software is written in ANSI C. A single 2 PC CGF workstation can support up to approximately 12 simulated entities. The system has been tested with as many as 30 external entities on the network; we suspect that the system would have difficulty dealing with more external network traffic than that. The current version of the CGF system uses either the SIMNET or the DIS protocol, selected at compile-time.

During the period leading up to the I/ITSC demo, participants may wish to connect to IST's DIS network and test specific network interactions, such as fire and detonation sequences, collisions, etc. IST will use the CGF system to provide the vehicles and other entities needed for these tests. Such tests are at the discretion of the participants; they should be arranged in advance. In this role, the CGF system will exemplify the DIS protocol, as known and implemented at IST.

Support at the I/ITSC demonstration: The IST CGF System will act in support at the Interop Demo, providing two functions, an LHD and Targets.

For the benefit of those participants and scenarios that require a helicopter carrier, the IST CGF System will generate a LHD (Wasp class) helicopter carrier. The representation will be extremely simple, as the LHD is being generated primarily to provide a landing site for the benefit of RWA simulators.

Once created, the LHD will move steadily along a simple racetrack path at a steady speed of 20 knots; see the diagram below. While turning the LHD will heel approximately 10 degrees to port (to the outside of the turn). The transitions from 0 degrees to 10 degrees and from 10 degrees to 0 degrees will take approximately 10 seconds. The LHD has no other behaviors or capabilities; specifically, it will not respond to incoming Detonation PDUs.

The IST CGF System will provide target entities so that other participants can have a predictable set of targets for their demonstrations. Target entities, or targets, will appear to be ordinary simulation entities (i.e. their Entity State PDUs will be normal) in all respects except for their behavior.

Targets can be created at any location in the scenario terrain. They can be assigned a route, which may be either an open path or a closed loop. Once created, a target will follow its assigned path. Upon reaching the end of a closed loop path, the target will repeat the path indefinitely. A target on an open path will stop at the end of that path.

Targets will, of course, react to incoming Detonation PDUs as specified in the 'Matrix of Munition Type x Entity Type' prepared by IST. Once destroyed, the target will go through the normal SIMNET burn sequence, culminating in the 'blackened hulk' stage (this sequence takes almost 30 minutes in SIMNET, but will be reduced to about 6 minutes for a target). After 2 minutes as a blackened hulk, a destroyed target will disappear from the battlefield. One minute later, the target will be reconstituted at its creation point and again begin following its path.

Targets will not react to events in the simulation around them, i.e. they will not attempt to avoid hostile entities. They will not fire their weapons.

Defining a target or set of targets requires advance preparation to fine tune the positions, routes, etc. Demo participants who would like to use IST provided targets should arrange for that support in advance. IST (CGF Group) will provide the following air targets:

A-10's
Su-25's
Havoc's
Apache's

The models provided will be limited in quantity and will exhibit very simple behavior (a simple racetrack).

Questions:

(1) Is the LHD speed of 20 knots acceptable to its users?

(2) Does anyone need to attack the LHD?

(3) Do the burn and reappear times for targets seem suitable?

(4) Should targets detect and process collisions?

(5) Note that current plans provide for only ground vehicles as targets. Are aircraft or ships needed as targets by any participants?

Since no response was received from the demo players, this item is closed (9/23/92).
STATUS: CLOSED. (9/23/92)

ACTION 50: IST will update its Test Procedures document in approximately 2-3 weeks. IST will disposition comments received prior to 8/20/92 by either incorporation into a revised document or by explanation to the author. All substantative comments received prior to 8/18/92 were discussed during the meeting on 8/20/92. Additional comments were received on 8/18/92, but not discussed or dispositioned, on 8/20/92. Additional comments received after 8/20/92 will be incorporated or dispositioned (if incorporation is not appropriate) with the author. Incorporation will be dependent upon the date a comment is received (the earlier received the higher the probability of incorporation), the severity of the comment (technical errors as contrasted to readability errors), and the extent of testing already conducted when the comment is received (IST must ensure uniformity in testing).
Comments Received on Test Procedures:
Page 5, Paragraph 1.1.1.1.2 - Sample frame; test data should be fire PDU.
Page 9, Paragraph 2 - PDU tests; time stamp field should be all zeros.
Page 13, Paragraph 2.3 - Parts field should be "omitted" or "don't care".
Page ?, Paragraph 3.1 - Terrain orientation comparison testing. Will add ships. All that is needed are PDUs from companies (unobtrusive testing).
Schedules for testing Aug. 12 - ready Aug. 15.
Page 20, Paragraph 4.2.1 - Location is consistent.
Section 0.3 - Change wording; do not want to implement.
Section 3.2
Section 4.2.1
Why 675 BAMS? For one meter accuracy.
Section 4.1.1.1 - Set time stamp; change wording.
Section 4.2.1 - Routing; Right Isosceles Triangle.
Section 4.3.1.2 - Test this feature.
Section 4.3.1.5
Section 5.2.20.1 - Bounding volume is of fixed dimensions.
Section 5.3
(8/20/92).
The rehearsal ground rules will be sent out in a week (9/23/92).
STATUS: OPEN. (9/23/92)

ACTION 51: Gamini Bulumulle briefed on steps to follow to gain access to the test network:
Serial line internet protocol (SLIP) or point to point protocol (PPP) must properly perform on the remote computers/simulators before anybody may gain access to the network. Please telephone IST in advance for a schedule appointment. Use this number for scheduling:

407-658-5512

During the scheduled time dial into IST using the following telephone numbers:

1-800-226-5023
1-800-226-5042

Remote users should get the following "login" prompt:

Netblazer login:
password: (enter issued password)

Separate Login names and Passwords will be assigned to each remote user. If SLIP or PPP installation is done properly then the remote login user should get the following message:

"Packet Mode Enable"

which indicates the TCP connection with the IST network. Presently, the test network at IST contains only "Data logger" and "SAFOR" but other hardware and test features will be added to the network in the near future. Since UDP/IP broadcast mode will be used for testing purposes each node at the network will receive all of the broadcasted PDUs.
Public domain (SUN) SLIP can be accessed by typing:

FTP WUARCHIVE.WUSTL.edu

Public domain (SUN) PPP can be accessed by typing:

next2.ist.ucf.edu
132.170.190.2

Gamini requested the following information from all demo players:

IP address
Login name
Password (provided by Gamini)
SLIP/PPP

STATUS: CLOSED. (9/23/92)

APPENDIX B

INTERCOVERSIONS BETWEEN DIFFERENT COORDINATE SYSTEMS

INTERCONVERSIONS BETWEEN DIFFERENT COORDINATE SYSTEMS

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Abstract

There are several different coordinate systems which can be used to describe the position, orientation, and motion of the entities in a simulation exercise. The coordinate systems that are referenced in this paper are the geocentric, geodetic and topocentric coordinate systems. A detailed study made on previously published coordinate conversion algorithms and any encountered problems are presented here. In converting geocentric to geodetic coordinates, four different algorithms yielding the same results are presented. The conclusions drawn from these analyses illustrate that by deriving a set of parametric equations and then utilizing Newton-Raphson's convergence algorithm results in the fastest and most accurate geocentric to geodetic coordinate conversion. In the case of a topocentric to geocentric conversion, it was discovered that the referenced algorithm was inaccurate. The corrected equations are given in this paper.

Introduction

The advent of affordable intercomputer communications networks has made possible the interconnection of simulators so as to allow for real-time interactive training. The precursor to Distributed Interactive Simulation (DIS) was a Defense Advanced Research Projects Agency (DARPA) sponsored program call Simulator Networking (SIMNET). In the SIMNET program, DARPA successfully demonstrated the feasibility of interconnecting multiple distributed simulators, primarily ground based armor vehicles, via a local area network (Ethernet) such that the simulators could interact in real-time. DIS is based upon the foundation of SIMNET and will be enhanced and expanded to provide the standard for future communication of simulators. Due to the expansion of a DIS exercise, simulators will be operating at larger geographic distances. As a result of this requirement, the geocentric coordinate system was chosen to

be the earth-fixed-axis coordinate system vice the flat-earth topocentric coordinate system in SIMNET exercises.

The geocentric coordinate system is defined as the earth-fixed coordinate system with the origin at the centroid of the earth, the x-axis passing through the Prime Meridian at the Equator, the y-axis passing through 90 degrees East longitude at the Equator, and the z-axis passing through the North Pole. The topocentric coordinate system is defined with the origin centered at a selected point on the Earth's surface and aligned at the selected point with East, North, and Up.

In order to establish the coordinate transformation between the two coordinate systems described, a third coordinate system, the geodetic coordinate, will be introduced. The geodetic coordinate is defined using three quantities: latitude, longitude, and the geodetic height. The latter defines the position of a point on the surface of the Earth with respect to the reference ellipsoid. In DIS, the shape of the earth is specified using the World Geodetic System 1984 (WGS84). To define a geodetic coordinate system, the surface of the earth is approximated by a reference ellipsoid which is an ellipsoid of revolution defined by two parameters: the equatorial radius a = 6,378,137 meters (the semimajor axis of the ellipse) and the flattening f = 1/298.257223563. If the polar radius (the semiminor axis of the ellipse) is denoted as b, then b = a * (1-f).

Interconversion From Geodetic to Geocentric

The process of converting between geodetic and geocentric coordinate systems involves transforming a given point in geodetic coordinates with quantities of latitude (ø), longitude (λ), and height (h), into the geocentric cartesian coordinates (X,Y,Z). The approach taken in [1] relies on trigonometry to perform the interconversion. The algorithm in [1] for geodetic to geocentric conversion is accurate and efficient with two minor corrections as described in [3]. The solution presented is an exact solution and the equations are similar to the ones presented in the Military Handbook [2]. The equations are presented below for completeness.

$$X = (R_n + h)\cos\phi\cos\lambda \tag{1}$$

$$Y = (R_n + h)\cos\phi\sin\lambda \tag{2}$$

$$Z = \left(\frac{b^2}{a^2}R_n + h\right)\sin\phi \tag{3}$$

where R_n is defined as the radius of curvature in the prime vertical and is defined by

$$R_n = \frac{a^2}{\sqrt{a^2\cos^2\phi + b^2\sin^2\phi}} \tag{4}$$

Interconversion From Geocentric to Geodetic

The interconversion process involved in converting a geocentric into a geodetic coordinate is more complicated than the previous conversion. The desired solution is to locate the point on the reference ellipsoid that is closest to the original point. The algorithm given in [1] has some errors in the derivation, which are corrected by [3]. However, the results from [1] still do not converge for realistic altitude values in modeling flight simulations. The algorithm given in [2] does converge; however, due to the excessive use of trigonometric functions, it is considerably slower than [3]. The approach taken by [3] does not rely on trigonometry, but instead uses a constrained optimization using Langrange multipliers and the multiplier is then adjusted for convergence. The termination is based on an approximate error measure term.

A different algorithm will be presented here that does not assume the earth to be a sphere in its iteration process. This algorithm will be referred to as algorithm 4. The intention is to compare this approach with the algorithm described in [3], and conclude if the approach is justified. The equation of the reference ellipsoid is as follows,

$$\Phi(x,y,z) = \frac{x^2}{a^2} + \frac{y^2}{a^2} + \frac{z^2}{b^2} - 1 = 0 \tag{5}$$

where a = 6378137m and b = 6356752m, denoting the semimajor and semiminor axis respectively. Let the set of geocentric coordinates (X,Y,Z) be the original point and (x,y,z) be any point in space. Define a vector $\bar{\rho}$,

$$\bar{\rho} = (X - x)\bar{i} + (Y - y)\bar{j} + (Z - z)\bar{k} \tag{6}$$

to be a vector connecting the two given coordinates. Taking the gradient of eq. (5) will result in a vector normal to the tangent at point (x,y,z). This vector is defined as follows:

$$\bar{n} = \nabla\Phi(x,y,z) = \frac{2}{a^2}x\bar{i} + \frac{2}{a^2}y\bar{j} + \frac{2}{b^2}z\bar{k} \qquad (7)$$

By defining the relationship between the two vectors, $\bar{\rho}$ and $\bar{n}$, as

$$\bar{\rho} = m\bar{n} \qquad (8)$$

where m is a constant, the vector $\bar{\rho}$ is constrained to pass through the point (x,y,z) normal to the ellipsoidal surface. From eqs. (6) and (7), a set of parametric equations of a straight line in space (where m is the parameter) is defined:

$$x = \frac{1}{1 + \left(\frac{2m}{a^2}\right)}X \qquad (9)$$

$$y = \frac{1}{1 + \left(\frac{2m}{a^2}\right)}Y \qquad (10)$$

$$z = \frac{1}{1 + \left(\frac{2m}{b^2}\right)}Z \qquad (11)$$

Substituting eqs. (9), (10), (11) into eq. (5) will constrain (x,y,z) to be on the surface of the ellipsoid. The substitution results are defined by f(m),

$$f(m) = \frac{W^2}{\left[a + \frac{2m}{a}\right]^2} + \frac{Z^2}{\left[b + \frac{2m}{b}\right]^2} - 1 = 0 \qquad (12)$$

where $W^2 = X^2 + Y^2$. An iterative numerical approach can be used to determine m, at which time x, y, z, and h can be calculated with the derived equations. Using the Newton-Raphson method for convergence, the value of m can be solved. In order to use Newton-Raphson's algorithm, the derivative of f(m) must be found. This results in the following:

$$f'(m) = \frac{df}{dm} = \frac{-4W^2}{a\left(a + \frac{2m}{a}\right)^3} - \frac{4Z^2}{b\left(b + \frac{2m}{b}\right)^3} \tag{13}$$

The essential algorithm is to first guess a value for m. In the comparison study with algorithm [3], m was set to zero. With this value, substitute into eqs. (9), (10), and (11) to determine the initial set of coordinates. With the first set of x, y, and z points, calculate h with the following equation:

$$h = \sqrt{(X - x)^2 + (Y - y)^2 + (Z - z)^2} \tag{14}$$

Our test for convergence is met if the new calculated h is less than or equal to the previous h by 50 cm, as described in the following equation.

$$|h_i - h_{i-1}| \leq 0.5 \quad \text{where } i = 1, 2, 3, \ldots \tag{15}$$

If eq. (15) is not satisfied, a new value for m must be calculated by following the Newton-Raphson convergence algorithm described below:

$$m_i = m_{i-1} - \frac{f(m_{i-1})}{f'(m_{i-1})} \quad \text{where } i = 1, 2, 3, \ldots \tag{16}$$

With the new m, the convergence process must be reiterated until eq. (15) is satisfied. When convergence is satisfied, x, y, z, and h have been determined by using eqs. (9), (10), (11) and (14). The longitude and latitude is easily computed by using the formulas below:

$$\lambda = \tan^{-1}\left(\frac{y}{x}\right) \tag{17}$$

$$\phi = \tan^{-1}\left(\frac{a^2}{bw}\right)\sqrt{1 - \frac{w^2}{a^2}} \tag{18}$$

where

$$w = \sqrt{x^2 + y^2} \tag{19}$$

The equations derived above are the equations used to perform a geocentric to geodetic coordinate system conversion. The algorithm is best described by a flowchart. This is shown in Figure 1.

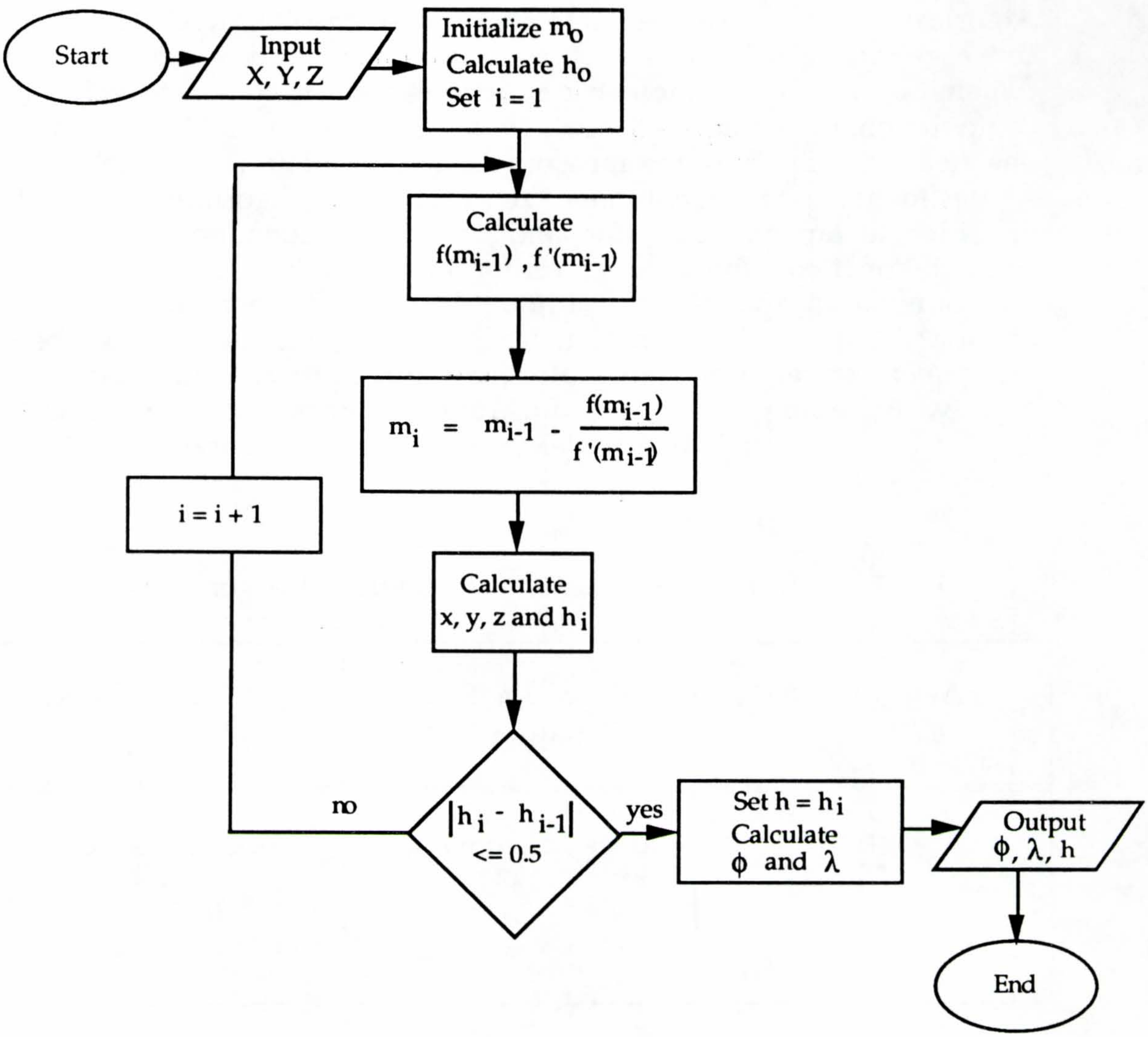

Figure 1: Geocentric to Geodetic Conversion Algorithm.

Comparisons on Different Geocentric to Geodetic Conversion Algorithms

Three algorithms ([1], [2], [3]) were referenced in the previous section, and a new one was presented in detail. This section will attempt to choose one of the four algorithms that best suits a real-time simulation environment. Algorithm [1] has to be eliminated because the iterative step fails to converge for high altitudes, such as those encountered in modeling flight dynamics. In [2], trigonometric functions were used extensively. The computational cost of using a trigonometric function is 12 floats, where one float is defined as the measure of a computational cost in using a single floating point operation. Each iteration in algorithm [2] requires one inverse tangent, one sine and one cosine function. Due to the computational cost involved, algorithm [2] is not recommended for real-time simulation applications, although it has been proven to converge and to be accurate. The algorithm described in [3] and the one described in this paper converge and are both accurate. Both algorithms converge quickly. For example, at a height of 165,000 meters, both converge in two steps. The measured time for each algorithm is illustrated in Table 1 below.

Table 1: Measured Time for the Different Algorithms

Algorithm #	time used for 1 million iterations (sec)	per iteration (sec)
[1]	does not converge	does not converge
[2]	103	1.03E-04
[3]	95	0.95E-04
4	86	0.86E-04

The measured time was taken at one million iterations and the average value was noted. This procedure was performed to overcome any side-effects of running only one iteration. The measurements shown were taken from a Sun SPARCWorkstation. As can be seen from the table above, alorithm [2] takes the longest time to compute one iteration. The algorithm presented in this paper took only 0.86E-04 seconds for one iteration; this is a 19.77% improvement to algorithm [2].

Several runs at different altitudes were taken for the two fastest algorithms, namely, [3] and 4. These values were generated at a latitude of 35N, and a longitude of 40E, and a final tolerance at 50cm. The conversion from geodetic to geocentric coordinates was done using the algorithm in [1] with the corrections noted in [3]. The results are tabulated in the Table 2 for algorithm [3] and Table 3 for algorithm 4.

Table 2: Algorithm [3] Results for Varying Heights.

Given Height (m)	Latitude (deg)	Longitude (deg)	Height (m)
1500	34.999999	40.000000	1499.956301
165000	34.999998	40.000000	164999.882064
3000000	34.999998	40.000000	2999999.811030

Table 3: Algorithm 4 Results for Varying Heights.

Given Height (m)	Latitude (deg)	Longitude (deg)	Height (m)
1500	35.000000	40.000000	1500.000000
165000	35.000000	40.000000	165000.000000
3000000	35.000000	40.000000	3000000.000000

As can be seen from Tables 1, 2 and 3, the results for both algorithms have insignificant differences in either case. Both algorithms are accurate and fast for real-time simulation exercises. If, however, only one algorithm may be chosen, then the algorithm presented in this paper is the most accurate and the fastest.

Interconversion From Topocentric to Geocentric

The geometric relationship between geocentric and topocentric coordinates is shown in Figure 2 below. In order to perform the conversion from topocentric to geocentric, the topocentric coordinate system is rotated about three axes, then translated along its z axis to the origin of the geocentric coordinate system. The algorithm in [1] based their translation using a perfect sphere as their earth model. Due to this assumption, errors were introduced because the translation never passed through the center of the earth. The only time when translation passes through the center of the earth is when latitude is 0, +90 or -90 degrees. When the algorithm in [1] was used, differences as large as 20 km was observed when compared to a translation based on an ellipsoidal earth model.

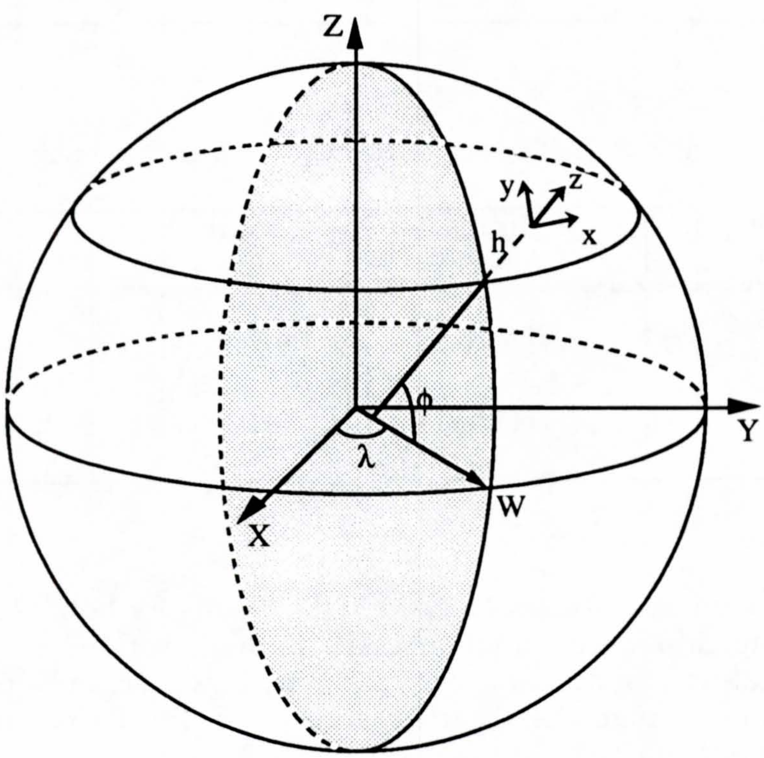

Figure 2: World Coordinate System.

The equation describing this interconversion using an ellipsoidal model can be stated as

$$\begin{Bmatrix} x_g \\ y_g \\ z_g \end{Bmatrix}_{XYZ} = [R]^T \begin{Bmatrix} x_t \\ y_t \\ z_t \end{Bmatrix}_{xyz} + \begin{Bmatrix} x_o \\ y_o \\ z_o \end{Bmatrix}_{XYZ} \tag{20}$$

where the subscripts g, t and o represent geocentric, topocentric and radius of the earth (from the center of the earth to the origin of the topocentric coordinate system) respectively. The XYZ subscript represents a geocentric earth-centered fixed axis, and the xyz subscript represents a topocentric fixed axis. The rotation matrix, R, in terms of latitude (ø), and longitude (λ), is given as

$$\begin{bmatrix} -\sin\lambda & \cos\lambda & 0 \\ -\sin\phi\cos\lambda & -\sin\phi\sin\lambda & \cos\phi \\ \cos\phi\cos\lambda & \cos\phi\sin\lambda & \sin\phi \end{bmatrix} \tag{21}$$

The topocentric coordinates are rotated to the geocentric coordinate system before being translated into the center of the earth. The coordinates x_o, y_o, and z_o can be computed by performing the interconversion between geodetic and geocentric coordinate system described in the above section given the latitude, longitude and height. Because the equations derived for the geodetic to geocentric coordinate system interconversion are based on an ellipsoidal model, the radius of curvature of the earth is taken into consideration.

Interconversion From Geocentric to Topocentric

This conversion is similar to the above algorithm. Solving eq. (20) for the topocentric coordinates results in the following:

$$\begin{Bmatrix} x_t \\ y_t \\ z_t \end{Bmatrix}_{xyz} = [R] \left(\begin{Bmatrix} x_g \\ y_g \\ z_g \end{Bmatrix}_{XYZ} - \begin{Bmatrix} x_o \\ y_o \\ z_o \end{Bmatrix}_{XYZ} \right) \tag{22}$$

where the rotation matrix, R, is expressed in eq. (21). The algorithm described in [1] made a translation of the coordinate system based on a perfect sphere and resulted in errors due to the ellipticity of the earth.

Conclusion

In conclusion, this paper has described the various interconversion algorithms for the three coordinate systems, namely, geocentric, geodetic and topocentric. For a geodetic to geocentric conversion, the algorithm presented in [1] had minor errors which have been corrected by [3]. These changes resulted in giving accurate and exact solutions. The results were compared with the algorithm presented in [2] and the results obtained were similar.

In the case of a geocentric to geodetic conversion, an approximation method is required. Algorithm [1] did not converge for realistic heights, therefore, it was eliminated. Algorithm [2] was slow for real-time networking, thus, it was also eliminated. The differences in results obtained from algorithms [3] and 4 were insignificant. However, if one algorithm must be chosen, algorithm 4 should be chosen for the following reasons. First, its per iteration of computation time was faster; and second, it converges to the exact initial values.

In the case of a topocentric to geocentric coordinate conversion, there was an error from paper [1]. The algorithms presented did not take the curvature of the earth into consideration. The equations were derived based on a pure spherical earth. This resulted in approximately a 20 km difference to an ellipsoidal earth at latitude regions of 45 degrees. The topocentric coordinates must be rotated to the geocentric coordinate system before the translation into the center of the earth.

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[1] Burchfiel, Jerry and Stephen Smyth. "Use of Global Coordinates in the SIMNET Protocol", *White Paper ASD-90-10, Second Workshop on Standards for Interoperability of Defense Simulations,* Orlando, FL, January 1990.

[2] "Datums, Projection, Grids and Common Coordinate Systems, Transformation of Department of Defense", *Military Handbook MIL-HDBK-600008,* May 1991.

[3] Wise, Ben. "Geocentric to Geodetic Coordinate Conversions", *BBN Report #7756,* May 1992.

APPENDIX C

THE ORIENTATION REPRESENTATION BETWEEN TOPOCENTRIC AND GEOCENTRIC COORDINATE SYSTEMS

THE ORIENTATION REPRESENTATION BETWEEN TOPOCENTRIC AND GEOCENTRIC COORDINATE SYSTEMS

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Abstract

The orientation of a vehicle can be described using Euler angles, which consist of an ordered set of three successive rotation angles. This paper describes the conversion process in transforming a set of Euler angles in one coordinate system into another. The two systems involved in the transformations are the topocentric and geocentric coordinate systems. The rotation matrices involved in transforming the body axis into the fixed-frame axis are derived for each of the coordinate systems, and a transformation from one fixed-frame coordinate system axis to another is presented. These derivations focus on distributed interative simulation applications, and the two simulation protocols referenced are the Simulator Networking (SIMNET) and Distributed Interactive Simulation (DIS) Protocols.

Introduction

In the computer simulation of the motion of a vehicle, the orientation of the vehicle is important for visual system representation. The orientation of the vehicle is important for other simulators to graphically display the entity in the battlefield and will have an impact on weapon dynamics and radar modeling. Due to this reason, the orientation information is periodically sent over the network.

In the SIMNET Protocols, the fixed-frame axis is defined as a right-handed Cartesian coordinate system, with the positive x-axis pointing east, the positive y-axis pointing north, and the positive z-axis pointing up. SIMNET requires the Cartesian coordinates to align with the local surface of the earth (topocentric coordinates) within a selectable exercise area.

Due to the need to increase simulation exercises encompassing larger geographic distances, the earth-centered, Cartesian coordinate (geocentric) is used as the fixed-frame axis in the DIS Protocols. The shape of the earth is described using the World Geodetic System 1984 (WGS84). The origin of the system is located at the centroid of the earth, with the X-axis passing through the Prime Meridian at the equator, the Y-axis passing through 90 degrees East longitude at the Equator, and the Z-axis passing through the North Pole.

Because of the differences in origin and orientation between the two coordinate systems, sets of Euler angles are interpreted differently on each coordinate system. The geocentric and topocentric coordinate axis are shown in Figure 1. The geocentric coordinate system is represented using capital letters (X, Y, Z) and the topocentric coordinate system is represented in small letters (x, y and z). The latitude and longitude are shown with symbols ø and λ respectively, and h defines the position of a point on the Earth's surface with respect to the reference ellipsoid.

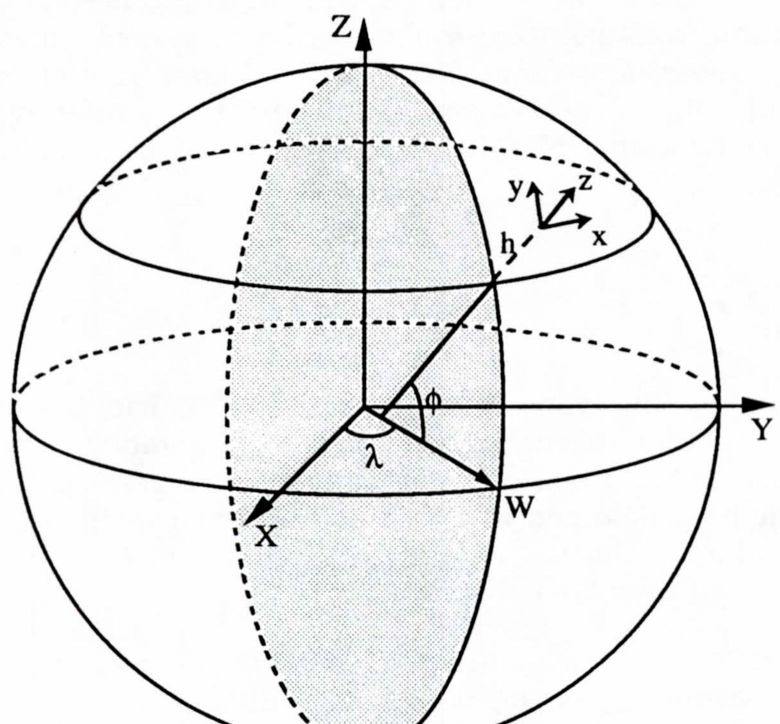

Figure 1: World Coordinate System

Orientation of Entitities in SIMNET

The orientation of a vehicle abiding by the SIMNET protocols is defined as the relative rotation between its body axis system and the fixed axis system. This orientation information is represented using a nine element rotation matrix that is transmitted in the Vehicle Appearance Protocol Data Unit (PDU) [1]. This rotation matrix can be written in terms of the Euler angles of rotation. Euler angles are the yaw, pitch and roll angles of rotation applied to the body in that order in the context of the SIMNET protocols [2].

In SIMNET, a vehicle's body axis is defined using a right-handed Cartesian coordinate system in meter-sized units; the body axis is defined with its x-axis pointing to the vehicle's right, its y-axis pointing to the vehicle's front, and its z-axis pointing up. This is shown in Figure 2.

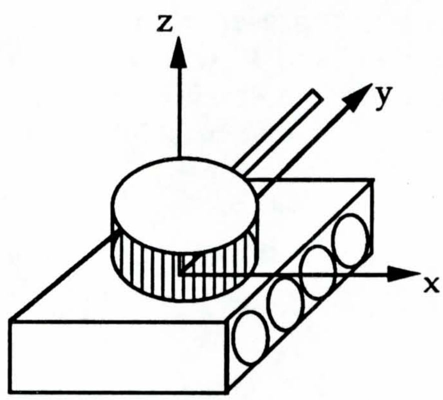

Figure 2: Body Axis in SIMNET

Positive yaw (Y') is a negative rotation about the z-axis to an intermediate frame B', defined with axis x', y' and z'. Positive pitch (P') is a positive rotation about the intermediate axis x' to another intermediate frame B" defined with axis x", y", and z", and positive roll (R') is a positive rotation about the intermediate axis y" to the final frame. The three Euler angle transformations in matrix form can be described as the following:

$$\begin{bmatrix} a_o \\ a_1 \\ a_2 \end{bmatrix} = [Y'][P'][R'] \begin{bmatrix} b_o \\ b_1 \\ b_2 \end{bmatrix}$$

where

$$[Y'] = \begin{bmatrix} \cos Y' & \sin Y' & 0 \\ -\sin Y' & \cos Y' & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

$$[P'] = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos P' & -\sin P' \\ 0 & \sin P' & \cos P' \end{bmatrix}$$

$$[R'] = \begin{bmatrix} \cos R' & 0 & \sin R' \\ 0 & 1 & 0 \\ -\sin R' & 0 & \cos R' \end{bmatrix}$$

(1)

The variables Y', P' and R' represent the yaw, pitch and roll of the vehicle in SIMNET respectively. The vector $[a_0, a_1, a_2]$ represents the fixed axis and the vector $[b_0, b_1, b_2]$ represents the body axis of the vehicle. Multiplying the matrices Y', P' and R' will result with the rotation matrix that is needed to perform the necessary transformation from a vehicle's body axis into the fixed axis. This matrix is defined as

$$\begin{bmatrix} \cos Y'\cos R' + \sin Y'\sin P'\sin R' & \sin Y'\cos P' & \cos Y'\sin R' - \sin Y'\sin P'\cos R' \\ -\sin Y'\cos R' + \cos Y'\sin P'\sin R' & \cos Y'\cos P' & -\sin Y'\sin R' - \cos Y'\sin P'\cos R' \\ -\cos P'\sin R' & \sin P' & \cos P'\cos R' \end{bmatrix}$$

(2)

and will be denoted as

$$\left[R_{body \to SIMNET}\right]$$

(3)

The rotation matrix to convert from SIMNET's fixed axis into the vehicle's body axis is defined as the transpose matrix of eq. (3), defined as

$$\left[R_{SIMNET \to body}\right]$$

(4)

Orientation of Entities in DIS

In DIS, the coordinate system representing the vehicle's body axis is also defined with a right-handed Cartesian coordinate system. However, the positive direction of the x-axis extends out to the front, the y-axis extends to the right side, and the z-axis extends downward of the vehicle [3], as shown in Figure 3 below. The difference in orientation will be considered in transforming between the two axes.

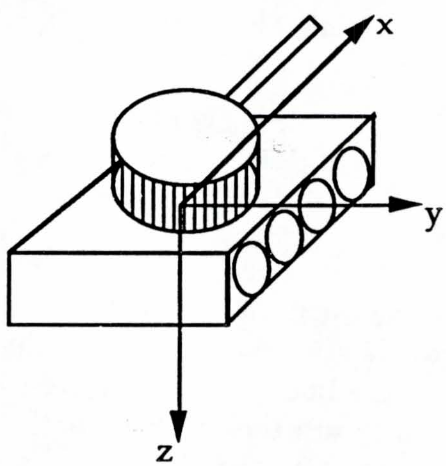

Figure 3: Body Axis in DIS

A set of three angles is used to describe the orientation of an entity; these angles describe three successive rotations about three different orthogonal axes. The order of rotation is yaw, pitch and roll in DIS. Positive yaw is a positive rotation about the z-axis to an intermediate frame B', defined with axes x', y' and z'. Positive pitch is a positive rotation about the intermediate axis y' to another intermediate frame B" defined with axes x", y", and z", and positive roll is a positive rotation about the intermediate axis x" to the final frame. The three Euler angle transformations in matrix form can be described as the following:

$$\begin{bmatrix} a_o \\ a_1 \\ a_2 \end{bmatrix} = [Y][P][R]\begin{bmatrix} b_o \\ b_1 \\ b_2 \end{bmatrix}$$

where

$$[Y] = \begin{bmatrix} \cos Y & -\sin Y & 0 \\ \sin Y & \cos Y & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

$$[P] = \begin{bmatrix} \cos P & 0 & \sin P \\ 0 & 1 & 0 \\ -\sin P & 0 & \cos P \end{bmatrix}$$

$$[R] = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos R & -\sin R \\ 0 & \sin R & \cos R \end{bmatrix} \tag{5}$$

The variables Y, P and R represent the yaw, pitch and roll of the vehicle in DIS respectively. The vector $[a_o, a_1, a_2]$ represents the fixed axis and the vector $[b_o, b_1, b_2]$ represents the body axis of the vehicle. Multiplying the matrices Y, P and R will result with the rotation matrix that is required to execute the transformation from a vehicle's body axis to fixed axis. This matrix is defined as

$$\begin{bmatrix} \cos P\cos Y & \cos P\sin Y & -\sin P \\ -\cos R\sin Y + \sin R\sin P\cos Y & \cos R\cos Y + \sin R\sin P\sin Y & \sin R\cos P \\ \sin R\sin Y + \cos R\sin P\cos Y & -\sin R\cos Y + \cos R\sin P\sin Y & \cos R\cos P \end{bmatrix} \tag{6}$$

and will be denoted as

$$\left[R_{body \rightarrow DIS}\right] \tag{7}$$

Transposing this matrix will provide the required matrix to transform a vehicle's fixed axis to body axis. This matrix is denoted with subscript $_{DIS \rightarrow body}$.

Conversion from Geocentric to Topocentric Fixed World Coordinate Axes

The transformation between the two fixed coordinate axes can be performed using a rotation matrix. This rotation matrix is represented as a matrix (3x3) in terms of the latitude (ø) and longitude (λ) of the topocentric coordinate system's origin with respect to the geocentric's system. The matrix required to perform a DIS into SIMNET fixed world coordinate axis is:

$$\left[R_{DIS \rightarrow SIMNET}\right] = \begin{bmatrix} -\sin\lambda & \cos\lambda & 0 \\ -\sin\phi\cos\lambda & -\sin\phi\sin\lambda & \cos\phi \\ \cos\phi\cos\lambda & \cos\phi\sin\lambda & \sin\phi \end{bmatrix} \quad (8)$$

The rotation matrix that is needed to perform a SIMNET into DIS fixed coordinate axis is the transpose matrix of eq. (8). This matrix is denoted with subscript $_{SIMNET \rightarrow DIS}$.

Relationship Between the Rotation Matrices

This section will illustrate the relationship between the rotation matrices derived in the previous sections. To differentiate the variables, SIMNET coordinate variables will be defined with primes. The rotation matrices, eqs. (4), (7), and (8), can be shown to have a relationship in terms of their individual set of Euler angles. Beginning with the relationship between the body axis and fixed axis, this can be expressed as

$$\begin{Bmatrix} x' \\ y' \\ z' \end{Bmatrix}_{body} = \left[R_{SIMNET \rightarrow body}\right] \begin{Bmatrix} X' \\ Y' \\ Z' \end{Bmatrix}_{fixed} \quad (9)$$

for SIMNET vehicles and

$$\begin{Bmatrix} x \\ y \\ z \end{Bmatrix}_{body} = \left[R_{DIS \rightarrow body}\right] \begin{Bmatrix} X \\ Y \\ Z \end{Bmatrix}_{fixed} \quad (10)$$

for DIS vehicles. The relationship between the SIMNET and DIS fixed axes can be described as

$$\begin{Bmatrix} X \\ Y \\ Z \end{Bmatrix}_{fixed} = \left[R_{SIMNET \rightarrow DIS}\right] \begin{Bmatrix} X' \\ Y' \\ Z' \end{Bmatrix}_{fixed} \tag{11}$$

Substituting eq. (11) into eq. (10) will result with the following expression,

$$\begin{Bmatrix} x \\ y \\ z \end{Bmatrix}_{body} = \left[R_{DIS \rightarrow body}\right]\left[R_{SIMNET \rightarrow DIS}\right] \begin{Bmatrix} X' \\ Y' \\ Z' \end{Bmatrix}_{fixed} \tag{12}$$

The vehicle's body coordinate system being represented in SIMNET differs from that of DIS and the relationship between the two may be described as the following:

$$\begin{Bmatrix} x \\ y \\ z \end{Bmatrix}_{body} = \left[R_{body}\right] \begin{Bmatrix} x' \\ y' \\ z' \end{Bmatrix}_{body} \tag{13}$$

where

$$\left[R_{body}\right] = \begin{bmatrix} 0 & 1 & 0 \\ 1 & 0 & 0 \\ 0 & 0 & -1 \end{bmatrix} \tag{14}$$

Eqs. (13) and (14) is obtained by observing Figures 2 and 3. Multiplying both sides of eq. (9) with eq. (14) results in the following:

$$\left[R_{body}\right] \begin{Bmatrix} x' \\ y' \\ z' \end{Bmatrix}_{body} = \left[R_{body}\right]\left[R_{SIMNET \rightarrow body}\right] \begin{Bmatrix} X' \\ Y' \\ Z' \end{Bmatrix}_{fixed} , \tag{15}$$

or

$$\begin{Bmatrix} x \\ y \\ z \end{Bmatrix}_{body} = [R_{body}]\left[R_{SIMNET \to body}\right]\begin{Bmatrix} X' \\ Y' \\ Z' \end{Bmatrix}_{fixed} \tag{16}$$

Utilizing eqs. (12) and (16), the following relationship is derived.

$$[R_{body}]\left[R_{SIMNET \to body}\right] = \left[R_{DIS \to body}\right]\left[R_{SIMNET \to DIS}\right] \tag{17}$$

This is the desired equation in terms of the rotation matrices when performing a conversion from a set of DIS Euler angles into SIMNET Euler angles. Similarly, the desired equation in performing a conversion from a set of SIMNET Euler angles to DIS Euler angles can be obtained by solving for the rotation matrix associated with DIS fixed axis into body axis. This results in the following equation,

$$\left[R_{DIS \to body}\right] = [R_{body}]\left[R_{SIMNET \to body}\right]\left[R_{DIS \to SIMNET}\right] \tag{18}$$

Obtaining SIMNET Euler Angles

The relationship between the rotation matrices was shown in the previous section. This section will derive a set of SIMNET Euler angles from a given set of DIS Euler angles. The attitude (roll, pitch, and yaw) of the vehicle will be expressed in a set of equations based on eq. (17). To simplify the derivations, eq. (17) is rewritten as

$$[B] = [A][C] \tag{19}$$

where

$$[B] = \begin{bmatrix} B_{11} & B_{12} & B_{13} \\ B_{21} & B_{22} & B_{23} \\ B_{31} & B_{32} & B_{33} \end{bmatrix} = [R_{body}]\left[R_{SIMNET \to body}\right] \tag{20}$$

$$[A] = \begin{bmatrix} A_{11} & A_{12} & A_{13} \\ A_{21} & A_{22} & A_{23} \\ A_{31} & A_{32} & A_{33} \end{bmatrix} = \left[R_{DIS \to body}\right] \tag{21}$$

and

$$[C] = \begin{bmatrix} C_{11} & C_{12} & C_{13} \\ C_{21} & C_{22} & C_{23} \\ C_{31} & C_{32} & C_{33} \end{bmatrix} = \left[R_{SIMNET \rightarrow DIS}\right] \quad (22)$$

The vehicle's pitch can easily be obtained from eqs. (20), (21) and (22) resulting in

$$\sin P' = B_{13} \quad (23)$$

$$P' = \sin^{-1}(B_{13}) \quad (24)$$

where $B13$ is defined as

$$B_{13} = \cos\phi\cos\lambda\cos P\cos Y + \cos\phi\sin\lambda\cos P\sin Y - \sin\phi\sin P \quad (25)$$

Similarly, from eqs. (20), (21) and (22), the yaw of the vehicle could be expressed as

$$Y' = \tan^{-1}\left(\frac{B_{11}}{B_{12}}\right) \quad (26)$$

where

$$B_{11} = -\sin\lambda\cos P\cos Y + \cos\lambda\cos P\sin Y \quad (27)$$

$$B_{12} = -\sin\phi\cos\lambda\cos P\cos Y - \sin\phi\sin\lambda\cos P\sin Y - \cos\phi\sin P \quad (28)$$

and the vehicle's roll is as follows:

$$R' = \tan^{-1}\left(\frac{B_{23}}{B_{33}}\right) \quad (29)$$

where

$$\begin{aligned} B_{23} = {} & \cos\phi\cos\lambda(-\cos R\sin Y + \sin R\sin P\cos Y) + \\ & \cos\phi\sin\lambda(\cos R\cos Y + \sin R\sin P\sin Y) + \\ & \sin\phi(\sin R\cos P) \end{aligned} \quad (30)$$

and

$$B_{33} = \cos\phi\cos\lambda(\sin R\sin Y + \cos R\sin P\cos Y) + \cos\phi\sin\lambda(-\sin R\cos Y + \cos R\sin P\sin Y) + \sin\phi(\cos R\cos P) \qquad (31)$$

Obtaining DIS Euler Angles

The previous section described how to obtain the SIMNET Euler angles of a vehicle. This section will provide a set of equations to calculate the desired DIS Euler angles from the known SIMNET Euler angles. The attitude (yaw, pitch and roll) of a vehicle will be determined from eq. (18). In order to simplify the discussion, eq. (18) may be rewritten as follows:

$$[A] = [B][C] \qquad (32)$$

where

$$[A] = \begin{bmatrix} A_{11} & A_{12} & A_{13} \\ A_{21} & A_{22} & A_{23} \\ A_{31} & A_{32} & A_{33} \end{bmatrix} = \left[R_{DIS \to body}\right] \qquad (33)$$

$$[B] = \begin{bmatrix} B_{11} & B_{12} & B_{13} \\ B_{21} & B_{22} & B_{23} \\ B_{31} & B_{32} & B_{33} \end{bmatrix} = [R_{body}]\left[R_{SIMNET \to body}\right] \qquad (34)$$

and

$$[C] = \begin{bmatrix} C_{11} & C_{12} & C_{13} \\ C_{21} & C_{22} & C_{23} \\ C_{31} & C_{32} & C_{33} \end{bmatrix} = \left[R_{DIS \to SIMNET}\right] \qquad (35)$$

The vehicle's pitch is easily obtained from eqs. (33), (34) and (35). Observing these equations, pitch can be expressed as the following:

$$P = \sin^{-1}(-A_{13}) \qquad (36)$$

where

$$A_{13} = \cos\phi\cos Y'\cos P' + \sin\phi\sin P' \tag{37}$$

Similarly, the vehicle's yaw can also be obtained from eqs. (33), (34) and (35) resulting in the following expression:

$$Y = \tan^{-1}\left(\frac{A_{12}}{A_{11}}\right) \tag{38}$$

where

$$A_{12} = \cos\lambda\sin Y'\cos P' - \sin\phi\sin\lambda\cos Y'\cos P' + \cos\phi\sin\lambda\sin P' \tag{39}$$

$$A_{11} = -\sin\lambda\sin Y'\cos P' - \sin\phi\cos\lambda\cos Y'\cos P' + \cos\phi\cos\lambda\sin P' \tag{40}$$

Finally, the vehicle's roll can be expressed as

$$R = \tan^{-1}\left(\frac{A_{23}}{A_{33}}\right) \tag{41}$$

where

$$A_{23} = \cos\phi(-\sin Y'\cos R' + \cos Y'\sin P'\sin R') - \sin\phi\cos P'\sin R' \tag{42}$$

and

$$A_{33} = \cos\phi(\sin Y'\sin R' + \cos Y'\sin P'\cos R') - \sin\phi\cos P'\cos R' \tag{43}$$

Conclusion

This paper has described a set of equations to perform conversion of Euler angles from one coordinate system into another, i.e. from geocentric to topocentric. It should be mentioned that transformations between Euler angles are computationally expensive. Excessive use of trigonometric functions are accountable to this factor. In order to reduce computational resources, a common coordinate axis should be chosen to allow all future simulators to participate in an exercise.

Another disadvantage in using Euler angles is having a singularity point occuring at a pitch angle of ±90°. Since DIS uses a geocentric coordinate system, the problem of singularity becomes a significant issue. For example, a ship passing the Equator heading north (or south) will have a pitch angle that is zero with respect to the local sea level but is 90° in a geocentric coordinate system. In fact, an infinitive number of examples could be described to cause singularities. This issue will be a major concern to the DIS standard if Euler angles are used to convey the orientation information of an entity.

REFERENCES

[1] Pope, Arthur and Richard Schaffer. "The SIMNET Network and Protocols", *BBN Report #7627, June 1991.*

[2] "BBN GT100 CIG to Simulation Host Interface Manual", *BBN Report #8912, July 1990.*

[3] "Military Standard (Final Draft) Protocol Data Units for Entity Information and Entity Interaction in a Distributed Interactive Simulation", *Institute for Simulation and Training Publication IST-PD-91-1, May 1992.*

APPENDIX D

TEST PROCEDURES (ORIGINAL VERSION)

Validation Tests
1992 I/ITSC Interoperability Demonstration

S.H. Smith, B.F. Goldiez

0 INTRODUCTION

The purpose of this document is to define the interoperability requirements for participating in the Distributed Interactive Simulation (DIS) Interservice/Industry Training Systems Conference (I/ITSC) interoperability demonstration. The level of interoperability defined is for this demonstration only and does not constitute conformance with the DIS standards for other applications.

0.1 Scope and Criteria

0.1.1 Scope

The tests described in this document are performed under the following set of assumptions:

Network Protocols. Each System Under Test (SUT) is required to be able to connect to and communicate with an Ethernet network. In addition, SUTs are required to use the User Datagram Protocol/Internet Protocol (UDP/IP). If the SUT is sending information on the network, it should be able to utilize the UDP/IP/Ethernet protocols to send and receive information. If the SUT is only receiving information from the network, it should be able to interpret UDP/IP/Ethernet protocols. DIS PDUs will be sent using broadcast mode. Non-DIS information will be sent using point-to-point services.

Application Messages. Each SUT is required to be able to interpret a subset of the DIS Protocol Data Units (PDUs) as defined in the May 8, 1992 draft of "Protocol Data Units for Entity Information and Entity Interaction in a Distributed Interactive Simulation", IST report IST-PD-91-1. The required PDUs are: Entity State, Weapons Fire, Detonation, and Collision. This document will verify that the above noted Protocol Data Units are correct with respect to syntax and consistent with respect to interpretation and utilization by a simulator. SUTs which send information on the network should be able to correctly build the appropriate PDUs according to the rules found in the DIS PDU standard. SUTs which only receive information should be able to correctly interpret the DIS PDUs.

Terrain, Feature, and Model Information. Each SUT is required to use the Project 2851 SIF data provided by the U.S. Air Force and PRC for development of terrain, feature, and dynamic entity models for use in the demonstration. Correlation of various terrain databases developed from the SIF data must be within specified limits for participation in the demo.

0.1.2 Criteria

Criteria refers to the standards upon which judgements are made. With respect to this document, criteria are the quantity of tests which must be successfully completed for a system to be judged interoperable. Criteria must, therefore, be consistent with the scope in a general sense and the specific tests (enumerated below) in precise terms. A simulator must meet all of the detailed requirements which follow to satisfactorily meet the criteria of interoperability associated with the I/ITSC demonstration.

0.2 Graduated Testing

0.2.1 Rationale

Validation testing is divided into a sequence of levels in an attempt to isolate problems in the System Under Test (SUT) at the lowest possible level. The tests proceed from basic communications tasks upward through progressively higher-order behavior.

The first test verifies that the SUT can transmit and receive information on the network using the UDP/IP/Ethernet protocols. Once communication is established, the SUT will be tested to ensure that the PDUs generated are correct with respect to syntax and consistent with respect to interpretation. The third test demonstrates that an entity is capable of moving around the terrain. The last test verifies that the entity can interact with other entities on the terrain.

0.2.2 Organization of the Test Levels

NETWORK LEVEL TESTS focus on verifying the ability to transmit and receive data packets using UDP/IP/Ethernet.

PDU TESTS verify the bi-directional exchange of Application Level Messages (PDUs) generated or interpreted by the SUT.

TERRAIN ELEVATION COMPARISON TESTS verify correlation between the Terrain Database (TDB) used by the SUT and a reference TDB.

APPEARANCE, LOCATION AND ATTITUDE TESTS verify proper generation and interpretation of location, orientation, and velocity information.

INTERACTIVITY TESTS verify that the SUT interacts appropriately with the rest of the simulation by generating events appropriately or by responding properly to externally generated events.

0.2.3 Test Modes

For each of the test levels described above, there are two modes of testing:

Transmission Test - SUT sends data, IST receives data

Reception Test - IST sends data, SUT receives data.

In Transmission mode, IST will verify that the SUT can generate and transmit the required data and will determine if the SUT has successful completed the test. In Reception mode, the SUT will be responsible for verifying that it is capable of receiving the IST generated information. Further analysis of the IST data is encouraged, not required.

SUTs that will be transmitting and receiving data (i.e., CGF and manned simulators) will be required to pass both Transmission and Reception tests. SUTs that will not be transmitting data (e.g., stealth, radar displays) will be required to pass the Reception Tests only.

0.3 Test Methods

The tests described in this document will be conducted by using either an IST supplied PC-based data logger or a dial-up facility provided by IST. Due to the limited bandwidth available (9600 baud) for the dial-up method, the prefered method of testing is the PC-based data logger. These two testing methods are described below.

0.3.1 Data Logger Method

For demonstration participants who have assembled a PC-based Data Logger at their site, files will be provided containing data packets for accomplishing the required interoperability tests. These files may be obtained via Internet electronic mail or on floppy disk (5 1/4" or 3 1/2" high density).

Tests that require the SUT to receive information (i.e., Reception Tests) for correct interpretation would utilize the Data Logger to issue pre-recorded packets found in the test files. Tests that require that the SUT send information to the IST test system (i.e., Transmission Tests) would utilize the Data Logger to record the information. This recorded data would be sent to IST for review using either of the above mentioned methods.

0.3.2 Dial-Up Method

Participants who do not have a PC-based Data Logger may conduct the tests described above using an extended Ethernet LAN implemented via a toll-free telephone link provided by IST. IST will record packets produced by the SUT and will play pre-recorded files when transmitting.

The SUT will need to use the Serial Line Internet Protocol (SLIP) or the Point to Point Protocol (PPP) for serial communications via the telephone link. Testing in this fashion will require coordination with IST via a separate voice connection.

1 NETWORK LEVEL TESTS

Specifying the appropriate addressing structures and data length fields is a prerequisite to being able to exchange DIS PDU's. Network Level Tests verify that the player can generate and interpret these addresses and the data lengths for the UDP/IP/Ethernet communication protocols.

Of necessity, some other checks must be performed; e.g. a limited check for byte ordering is implicit in examining the content of protocol header fields which are greater than one octet in length.

This is not a conformance test of the UDP/IP/Ethernet protocols; it is a test of only those fields which are important to the transfer of DIS PDUs, namely addressing and

data. Data integrity calculations, i.e. checksums, will not be checked other than to determine if the transmitted data has been corrupted. If the data has been corrupted, it will be discarded.

1.1 Broadcast Test

The SUT must demonstrate the capability to send and receive, in broadcast mode, UDP/IP/Ethernet packets in order to achieve interoperability in the I/ITSC Interoperability Demonstration. Testing this capability will be done in two steps. The first step is to test the SUTs ability to build and broadcast UDP/IP/Ethernet packets. The second step is to verify the SUTs ability to receive and interpret such data. The tests are described in the paragraphs that follow.

1.1.1 Transmission Test

To test broadcast transmission, as will be used in the Interoperability Demonstration to transmit DIS PDUs, the SUT will generate and transmit a packet whose data will be a Fire PDU. IST will capture the packet and verify correctness of the player's UDP, IP, and Ethernet header frames for the following fields: destination address, protocol address, data length, and data content.

Destination Address - Only destination addresses will be tested because DIS does not care where the data originates. These fields are found in the Ethernet and IP header frames.

Protocol Address - There are only three protocols (above the physical interface) to be used, viz. IP, UDP and DIS. Each protocol is identified in the preceding lower layer by a unique number. If these numbers are not used, the PDU will not reach the simulation destination. The tests will be conducted for both valid and invalid protocol numbers.

Data Length - At each layer of the communication stack, the PDU is encapsulated in protocol headers. In each protocol, the data length field represents the total size of the data (i.e., data + header) for that layer. The data length is represented in octets. The test will determine if the appropriate length is calculated for the Fire PDU.

Succesful completion of these tests shall be achieved if the SUT can generate and interpret destination addresses, protocol addresses, and data lengths for the test method in use.

1.1.1.1 Fields of Concern

Except where indicated by a prefix of 0x to indicate base 16 (hexadecimal), decimal values are specified below for all fields of concern. IST will verify that the correct values appear in all fields.

Destination Address

Ethernet Dest Address	=	255-255-255-255-255-255 (all bits set TRUE)
IP Destination Address	=	132.170.191.255

Protocol Address

Ethernet Type Field	=	6 // IP
IP Protocol Field	=	17 // UDP
UDP Port Number	=	3000 // DIS Application

Data Length

Ethernet Length Field	=	4 (LLC length) + 20 (IP length) + 8 (UDP length) + length of UDP data in octets
IP Length Field	=	20 (IP length) + 8 (UDP length) + length of UDP data in octets
UDP Length Field	=	8 (UDP length) + length of UDP data in octets

1.1.1.2 Sample Frame

In all cases in this document fields marked with DC (Don't Care) will not be checked.

Ethernet Frame

preamble	=	DC
start frame delim.	=	DC
dest. address	=	255-255-255-255-255-255
source address	=	DC
type	=	0x0800

IP Frame

version	=	4
IHL	=	DC
type of service	=	DC
total length	=	20 (IP length in octets) + 8 (UDP length in octets) + length (in octets) of UDP data
identification	=	DC
fragmentation offset	=	0
time to live	=	DC
protocol	=	17
header checksum	=	DC
source address	=	DC
dest. address	=	132.170.191.255

UDP Frame

source port	=	DC
dest. port	=	3000
length	=	8 (UDP length in octets) + length (in octets) of UDP data
checksum	=	DC
data	=	Fire PDU

1.1.2 Reception Test

To test the SUT's ability to receive UDP/IP/Ethernet packets, the IST test system will generate and transmit (in broadcast mode) the packet defined in 1.1.1.2 above. It is the responsibility of the SUT to verify that it receives the entire packet and interprets all fields correctly.

1.2 Point-to-Point Test

In the case where the SUT intends to use the I/ITSC interoperability network for non-DIS traffic, it is required that the information be sent using a unicast service (also called point-to-point). In this case, the SUT must demonstrate its ability to use this network service in order to be interoperable for the I/ITSC demo.

Since point-to-point traffic will be generated by demo participants, SUTs must expect such data and should be able to receive and subsequently reject such data without adverse affect on the SUT or the network. Demo participants not using the point-to-point services are still required to pass the point-to-point reception tests (see 1.2.3). SUTs that will be using point-to-point services (those sending non-DIS traffic) on the I/ITSC demo network are required to pass all tests described in this section.

As in the broadcast testing there are two steps to testing point-to-point network usage. The first step is to test the SUTs ability to build and transmit UDP/IP/Ethernet packets using point-to-point services. The second step is to verify the SUTs ability to receive and interpret such data. These tests, performed for the Dial-Up method only, are described in the paragraphs that follow.

1.2.1 Address Resolution Protocol (ARP)

In addition to the capability of sending and receiving information, the SUT must be able to implement ARP in order to obtain physical address information. In the point-to-point transmission test, the SUT will be given the IP address for the IST test system. Using the supplied IP address, the SUT must broadcast an ARP Request to the network. The IST system, recognizing the IP address, will respond to the ARP request with an ARP reply containing the Ethernet address of the IST test system. This Ethernet address will be used to establish point-to-point communications with the IST test system.

Similarly, in the point-to-point reception test, the SUT will supply the IST test system with its IP address. The IST test system will issue an ARP Request to the SUT supplied IP address. The SUT, recognizing its IP address, should respond with an ARP reply containing its Ethernet address. This Ethernet address will be used by the IST test system for point-to-point communications.

1.2.2 Transmission Test

To test point-to-point transmission, as will be used in the Interoperability Demonstration to transmit non-DIS data, the SUT will generate and transmit a packet whose data will be an example of the non-DIS data the participant will generate. IST will capture the packet and verify correctness of the player's UDP, IP, and Ethernet header frames for the following fields: destination address, protocol address, data length, and data content.

Succesful completion of these tests shall be achieved if the SUT can both generate and interpret destination addresses, protocol addresses, and data lengths for the test method in use.

1.2.2.1 Fields of Concern

Except where indicated by a prefix of 0x to indicate base 16 (hexadecimal), decimal values are specified below for all fields of concern. IST will verify that the correct values appear in all fields.

Destination Address

Ethernet Dest Address	=	xxx-xxx-xxx-xxx-xxx-xxx (determined by ARP)
IP Destination Address	=	xxx.xxx.xxx.xxx (tbd at time of test)

Protocol Address

Ethernet Type Field	=	6 // IP
IP Protocol Field	=	17 // UDP
UDP Port Number	=	3000 // DIS Application

Data Length

Ethernet Length Field	=	4 (LLC length) + 20 (IP length) + 8 (UDP length) + length of UDP data in octets
IP Length Field	=	20 (IP length) + 8 (UDP length) + length of UDP data in octets
UDP Length Field	=	8 (UDP length) + length of UDP data in octets

1.2.2.2 Sample Frame

In all cases in this document fields marked with DC (Don't Care) will not be checked.

<u>Ethernet Frame</u>

preamble	=	DC
start frame delim.	=	DC
dest. address	=	xxx-xxx-xxx-xxx-xxx-xxx (determined by ARP)
source address	=	DC
type	=	0x0800

<u>IP Frame</u>

version	=	4
IHL	=	DC
type of service	=	DC
total length	=	20 (IP length in octets) + 8 (UDP length in octets) + length (in octets) of UDP data
identification	=	DC
fragmentation offset	=	0
time to live	=	DC
protocol	=	17
header checksum	=	DC
source address	=	DC
dest. address	=	xxx.xxx.xxx.xxx (tbd at time of test)

<u>UDP Frame</u>

source port	=	DC
dest. port	=	3000
length	=	8 (UDP length in octets) + length (in octets) of UDP data
checksum	=	DC
data	=	non-DIS data

1.2.3 Reception Test

To test the SUT's ability to receive UDP/IP/Ethernet packets, the IST test system will generate and transmit (in point-to-point mode) the packet defined in 1.2.2.2. It is the responsibility of the SUT to verify that it receives the entire packet and discards it appropriately.

2 PDU TESTS

PDU Tests will be conducted to determine whether the SUT can build and interpret the Application Level Data structures defined by the DIS 1.0 Standard. Both Transmission and Reception tests will be conducted for each of the four required PDU types.

PDUs will be built using the values as specified in this section except where indicated. Values to be placed in fields marked "selected by SUT" will be provided at the time of the test by the operator of the SUT. The intent of the tests is to verify alignment, byte ordering, data types, etc., therefore the values specified below are not intended to realistically depict a specific vehicle at a specific location.

The number of articulation parameters in the Entity State PDU or Detonation PDU is indicated in the # OF ARTICULATION PARAMETERS (numPar) field. If the value of the numPar field is zero, the PDU is 1152 bits in length. If the value of the numPar field is greater than zero, this indicates how many ARTICULATION PARAMETERS the PDU carries, and the PDU is (1152 + 128 * numPar) bits long.

During Transmission Tests, IST will verify that the correct values appear in all the fields. If discrepancies arise, IST will attempt to determine the cause (e.g. byte ordering reversed, field not initialized, etc.).

During Reception Tests, the developer will verify that all fields are interpreted as intended.

Succesful completion of these tests shall be achieved if the SUT can transmit and receive each of the four required PDU types.

2.1 Entity State PDU

```
// PDU HEADER

header.version                          = 0x01
header.exercise                         = 0x01
header.kind                             = 0x01    // EntityState
header.unused_8                         = DC
```

```
// ENTITY ID

entityID.simulator.site              = selected by SUT
entityID.simulator.host              = selected by SUT
entityID.entity                      = selected by SUT


// VARIOUS DESCRIPTIVE FIELDS...

unused_8                             = DC
forceID                              = 0x0     //BLUE FORCE
entityType                           = selected by SUT

// guise should be 0 when unused

guise.entityKind                     = 0x00
guise.domain                         = 0x00
guise.country                        = 0x00
guise.category                       = 0x00
guise.sub_category                   = 0x00
guise.specific                       = 0x00
guise.extra                          = 0x00

// Standard says this is a 32 bit unsigned integer but least
// significant bit is a flag to indicate absolute or relative
// Therefore, mask out the low-order bit, then divide the high
// 31 bits by 2 to get the value. For this test, we'll specify
// a value of 0 time units, relative scheme

timeStamp                            = 0x00000000


// Entity Location, Velocity, and Orientation

location.x                           = 100.0 meters
location.y                           = 200.0 meters
location.z                           = 300.0 meters
velocity.x                           = 1.0 meters/sec
velocity.y                           = 2.0 meters/sec
velocity.z                           = 3.0 meters/sec


// 45 degrees, 22.5 degrees, 11.25 degrees

orientation.psi                      = 0x12345678 BAM
orientation.theta                    = 0x87654321 BAM
orientation.phi                      = 0x89ABCDEF BAM
```

```
// Dead Reckoning Parameters

deadReckonParms.algorithm              = 0x02    // use
                                                 DRM(F,P,W)
                                                 scheme


deadReckonParms.unused_8               = DC
deadReckonParms.unused_16              = DC
deadReckonParms.unused_32              = DC
deadReckonParms.unused_32_2            = DC
deadReckonParms.unused_32_3            = DC

deadReckonParms.acceleration.x         = 1.0 meters/sec/sec
deadReckonParms.acceleration.y         = 2.0 meters/sec/sec
deadReckonParms.acceleration.z         = 3.0 meters/sec/sec

deadReckonParms.angularVelocity.x      = 0x01234567 BAM/millisec
deadReckonParms.angularVelocity.y      = 0x56789ABC BAM/millisec
deadReckonParms.angularVelocity.z      = 0x12131415 BAM/millisec

// Appearance; All platforms (but not Life forms or
// Environmentals) can be depicted as DESTROYED so we'll
// set only that bit.

appearance                             = 0x00000001 //Destroyed


marking.characterSet                   = 0x01    // ASCII

marking.text                           = 'MARKINGTEXT'


// Does DIS Standard say what these capabilities mean?
// Assume it means that the entity can SUPPLY ammo or
// fuel or miscellaneous supplies or repairs TO OTHER
// ENTITIES. Make this entity able to supply
// all those services.

capabilities                           = 0x0000000F

// Padding

unused_16_2                            = DC
unused_8_2                             = DC

// Articulated Parts Array Size

numParts                               = 0x03
```

```
     // First record

          // A change occurred
parts[0].change                          = 0x0001

          // in a part that articulates with the hull
parts[0].partID                          = 0x0000

          // the part is the PRIMARY TURRET and
          // its AZIMUTH is modified
parts[0].numberParms                     = 4011

          // New turret azimuth parameter is 180 degrees
parts[0].partsParms                      = 0x80000000 //BAMs


     // Second record

          // A change occurred
parts[1].change                          = 0x0001

          // in a part that articulates with the first part
parts[1].partID                          = 0x0001

          // the part is the PRIMARY GUN and
          // its ELEVATION is modified
parts[1].numberParms                     = 4213

          // New gun elevation parameter is 45 degrees
parts[1].partsParms                      = 0x20000000 //BAMs


     // Third record

          // state that a change occurred
parts[2].change                          = 0x0001

          // in a part that articulates with the first part
parts[2].partID                          = 0x0001

          // the part is the PRIMARY GUN and
          // its ELEVATION  is modified
parts[2].numberParms                     = 4213


          // New gun elevation parameter is 45 degrees
parts[2].partsParms                      = 0x20000000 //BAMs
```

2.2 Fire PDU

```
// PDU HEADER

header.version                      = 0x01
header.exercise                     = 0x01
header.kind                         = 0x02    // Fire
header.unused_8                     = DC

// ID of firing entity

attackerID.simulator.site           = selected by SUT
attackerID.simulator.host           = selected by SUT
attackerID.entity                   = selected by SUT

// ID of intended target, arbitrary

targetID.simulator.site             = 4
targetID.simulator.host             = 5
targetID.entity                     = 6

// Make this a munition that must be flown, so it needs an ID

munitionID.simulator.site           = selected by SUT
munitionID.simulator.host           = selected by SUT
munitionID.entity                   = selected by SUT

eventID.simulator.site              = selected by SUT
eventID.simulator.host              = selected by SUT
eventID.entity                      = selected by SUT


// a value of 0 time units, relative scheme

timeStamp                           = 0x00000000


// Launch Location

location.x                          = 100.0 meters
location.y                          = 200.0 meters
location.z                          = 300.0 meters

burst.munition                      = selected by SUT
burst.warhead                       = 7000 // Nuclear
burst.fuze                          = 3000 //Proximity
burst.quantity                      = 1 // One nuke is enough
burst.rate                          = 1 // ditto
```

```
velocity.x                        = 100.0 meters/sec
velocity.y                        = 10.0 meters/sec
velocity.z                        = 1.0 meters/sec
range                             = 32767.0 meters
```

2.3 Detonation PDU

```
// PDU HEADER

header.version                    = 0x01
header.exercise                   = 0x01
header.kind                       = 0x03     // Detonation
header.unused_8                   = DC

// ID of firing entity

attackerID.simulator.site         = selected by SUT
attackerID.simulator.host         = selected by SUT
attackerID.entity                 = selected by SUT

// ID of intended target (arbitrary)

targetID.simulator.site           = 4
targetID.simulator.host           = 5
targetID.entity                   = 6

// Make this a munition that must be flown

munitionID.simulator.site         = selected by SUT
munitionID.simulator.host         = selected by SUT
munitionID.entity                 = selected by SUT

eventID.simulator.site            = selected by SUT
eventID.simulator.host            = selected by SUT
eventID.entity                    = selected by SUT

// a value of 5 time units, relative scheme

timeStamp                         = 0x00000000

worldLocation.x                   = 22003.56 meters
worldLocation.y                   = 3890.45 meters
worldLocation.z                   = 100.33 meters

burst.munition                    = selected by SUT
burst.warhead                     = 7000 // Nuclear
burst.fuze                        = 3000 //Proximity
burst.quantity                    = 1 // One nuke is enough
```

```
burst.rate                          = 1 // ditto
velocity.x                          = 100.0 meters/sec
velocity.y                          = 10.0 meters/sec
velocity.z                          = 1.0 meters/sec

entityLocation.x                    = 0.003 meters
entityLocation.y                    = 1.25 meters
entityLocation.z                    = 100.56 meters
result                              = 0 // detonation

numParts                            = 0

parts[0].change                     = DC
parts[0].partID                     = DC
parts[0].numberParms                = DC
parts[0].partsParms                 = DC
parts[1].change                     = DC
parts[1].partID                     = DC
parts[1].numberParms                = DC
parts[1].partsParms                 = DC
```

2.4 Collision PDU

```
// PDU HEADER

header.version                      = 0x01
header.exercise                     = 0x01
header.kind                         = 0x04     // Collision
header.unused_8                     = DC

issueID.simulator.site              = selected by SUT
issueID.simulator.host              = selected by SUT
issueID.entity                      = selected by SUT

collideID.simulator.site            = selected by SUT
collideID.simulator.host            = selected by SUT
collideID.entity                    = selected by SUT

eventID.simulator.site              = selected by SUT
eventID.simulator.host              = selected by SUT
eventID.entity                      = selected by SUT

unused_16                           = DC

// a value of 16 time units, relative scheme

timeStamp                           = 0x00000000
```

velocity.x	= 30.0 meters/sec
velocity.y	= 2.0 meters/sec
velocity.z	= 0.002 meters/sec
mass	= 3415.456 kg.
location.x	= 3.0 meters
location.y	= 0.15 meters
location.z	= 1.23456 meters

3 TERRAIN ORIENTATION COMPARISION TESTS

This test is applicable to entities which operate on the terrain or in close proximity to the terrain (within 100 meters of the terrain based on a vertical nadir struck from the entity's center of gravity or axis system origin). Correlation is necessary for successful interoperability since each participant will have separately converted the terrain database supplied by Project 2851. This test will be performed in Transmission mode only.

3.1 Orientation Transmission Tests

The following test shall be conducted. IST will receive Entity State PDU's based upon the following conditions.

An air entity being simulated will follow the following course: begin at Point Sierra Nevada (approximate coordinates of X=-2696540.363744, Y=-4429222.861145, Z=3701210.935812) and proceed at a constant speed and orientation relative to the ground along a straight line course toward Alder Peak (approximate coordinates of X=-2691159.422709, Y=-4414600.104341, Z=3724389.737460). Maintain 100' AGL.

A ground entity will travel at a constant speed from Point Sierra Nevada along a straight line to the Ocean View Mine (approximate coordinates of X=-2681421.398590, Y=-4439201.79 9243, Z=3701708.953223) following the terrain.

A sea entity will travel at a constant speed beginning at point X=-2707720.507913, Y=-4418598.279712, Z=3705714.714867 along a straight line to the approximate coordinates of X=-2698472.311416, Y=-4417916.999591, Z=3713214.809309).

Ground, sea, and air entities shall follow a specific course as described above. IST will make at least three samplings (at points chosen by IST, but not revealed to the SUT) of Entity State PDU's. IST will also determine the polygon which

includes the intersection of the vehicle nadir with the terrain and will compute the absolute location of that intersection with the polygon. The nadir will be determined by examining the Entity State PDU Entity Location fields. The polygon's vertices will be determined by IST based upon IST's semi-automated forces testbed version of the terrain data base (unless another polygonal representation is made available to IST).

IST will compute a normal vector using the three vertices of the terrain polygon described above. If the polygon contains more than three vertices, three consecutive vertices shall be selected at random. The terrain polygon's normal vector shall be decomposed into its component Euler angles based upon its position relative to the geocentric earth and using the assumption that the terrain polygon's normal vector is the same as the polygons local z-axis.

Succesful completion of these tests shall be achieved if at least one Euler angle of the terrain polygon surface normal vector is within 36,000,000 BAM's (approximately 3 degrees) of the reference entity's Euler angle. Visual observation will also be made of this test to note any anomalies not detected in the analytical data.

4 APPEARANCE TESTS

Tests in this section are intended to validate the algorithms used by the SUT to determine and interpret location, attitude, and velocity information, position of articulated parts, and special appearance indications.

4.1 Location and Attitude Tests

Tests in this section shall be made to determine proper interpretation of location and orientation structures used in entity state PDUs. Only the Entity State PDU is used for this section of tests. The Protocol Version, Exercise Identifier, Padding, Entity ID, ForceID, Entity Type, and Alternate Entity Type fields are not evaluated on this set of tests; therefore, their values are not relevant. Unless stated otherwise, all velocities and accelerations shall be equal to zero. These tests will be performed in both Transmission and Reception modes.

4.1.1 Location Tests

Tests in this section ensure that the Entity Location is interpreted uniformly between simulators. The Entity Location and time stamp fields of the Entity State PDU are the primary fields studied in this section.

Succesful completion of these tests shall be achieved if the location of the entity (origin) is within 1 meter (measured along any single axis) and if new PDU's are transmitted at a rate of .2 Hz. The value of 1 meter was determined based upon the approximate value of 675 BAMS*Semi-Major axis of the Earth (meters). The value of .2 Hz is based upon the DIS default value found in paragraph 4.7.2.1.3.c (minimum issue of once every 5 seconds) of the DIS Standard.

Step 1:
The SUT shall position a stationary entity on the terrain surface at the southwest corner of the gaming area. The SUT shall then send Entity State PDUs for a period of one minute.

IST will check the resulting PDUs to verify that all fields in the Entity State PDU remain the same except for the time stamp. IST will also verify that the PDUs are sent at the correct frequency by analyzing the timestamp field.

Step 2:
Relocate (instantaneously BEAM) the entity listed above from its initial position to each of the following positions and generate one PDU at each new location.

- X = -2709413.024104
  Y = -4421360.215115
  Z = 3701210.935812

- X = -2652154.227640
  Y = -4425581.830435
  Z = 3744003.785569

4.1.2 Attitude Tests

Tests in this section shall be made to validate consistent interpretation of axis system orientation in the DIS Standard. Tests in this section primarily use the Entity Orientation field of the Entity State PDU.

Succesful completion of these tests shall be achieved if the actual orientation, as measured by each Euler angle, is within 675 BAM's of the commanded orientation. The tolerance is to ensure an accuracy of approximately 1 meter if the angular deviation is multiplied by the Semi-Major axis of the earth (per WGS 84). Positional accuracy shall be within 1 meter along any axis.

STEP 1:
At the coordinates of X=6378137.0, Y=0.0, Z=0.0 create an axis system with the x-axis oriented to the local east (i.e., aligned to be parallel with line of latitude), the y-axis oriented to the local north (i.e., aligned to be parallel with the line of longitude), and the z-axis perpendicular to the x and y axes and oriented to create a right hand cartesian coordinate system. Record the Euler angles (in the Entity Orientation field of an Entity State PDU) between this local axis system and the reference axis system (i.e., WGS 84).

STEP 2:
With the axis system established as above, perform the following rotations in sequence. After each rotation, record the Euler angles (using the Entity Orientation field of a new Entity State PDU) between the local axis system and the reference axis system. The rotations below shall be understood as angular displacements from the initial position.

Pitch = 1073741824 BAMS
Pitch = -1073741824 BAMS
Roll = 2147483648 BAMS
Roll = -2147483648 BAMS
Yaw = 3221225472 BAMS
Yaw = -3221225472 BAMS
Pitch = 536870912 BAMS
Roll = 2147483648 BAMS
Yaw = 3221225472 BAMS

STEP 3:
Orient the local axis system from step 1 as follows; the origin shall be located at X=-2650618.45033, Y=-4423019.118142, Z=3741821.1509920. The x-axis shall be oriented positive south and parallel to the origin's longitude. The y-axis shall be oriented positive west and parallel to the origin's latitude. The z-axis shall be perpendicular to the x and y axes and oriented to yield a right hand cartesian coordinate system. Record the Euler

angle (using the Entity Orientation field of an Entity State PDU) between this local axis system and the reference axis system.

STEP 4:
Same as Step 2 above.

4.2 Dead Reckoning Validation

This section will build upon tests conducted in 4.1, above to test the consistency between a simulator's representation of linear velocity, orientation, and other dead reckoning parameters. These tests will be performed in both Transmission and Reception modes.

4.2.1 Linear Velocity Validation

Begin moving the entity in a straight line to the east (parallel to the Equator). When the entity crosses the beginning coordinates defined in section 3.1, it should be at a constant velocity of:

tank	5 m/s
ship	20 m/s
helo	100 m/s
aircraft	300 m/s

Continue in a straight line with a constant velocity until the entity crosses the end coordinates defined in section 3.1. IST will record the PDUs generated and will examine the position, velocity, and time stamps to verify internal consistency in the PDUs. Succesful completion of these tests shall be achieved if the entity crosses the designated end point (within 1 m) within 200ms of the idealized time necessary to traverse the linear distance at a constant velocity.

4.2.2 Angular Velocity Validation

A validation test for angular velocity is not required for the Interoperability Demonstration.

4.2.3 Linear Acceleration Validation

A validation test for linear acceleration is not required for the Interoperability Demonstration.

4.3 Appearance Validation

This set of tests shall verify the proper use of Entity Type, Entity Appearance, Entity Marking, Capabilities, # Articulation Parameters, and Articulation Parameters fields in the Entity State PDU.

4.3.1 Entity Type Validation

Generate an entity state PDU in sequence for each of the entity types listed in the IST Entity Type Sheet of 6/4/92. The only field to be examined will be the entity type field.

4.3.1.1 Entity Appearance Validation

The basic assumption for the I/ITSC demo is that an entity is either active or destroyed. Therefore, a validation test for destroyed entities will be required for the interoperability demo. Many of the entities could go through a destruction sequence of flamming, smoking, and finally destroyed. For I/ITSC, the destroyed state is represented visually by a black coloring of the destroyed entity. For all destroyed entities, the bit 0 (zero) of the Entity Appearance field of the Entity State PDU should be set to indicate its destruction (as shown in section 2.1). The SUT can go through any destruction sequence as long as this bit is set within 15 seconds of destruction.

In the ground case, the SUT will create a stationary vehicle on the ground at Lockwood Post Office (approximate location of X=-2669926.874155, Y=-4428900.674144, Z=3720707.134921). In the surface case, the SUT will create a ship at anchor (approximate location X=-2716162.393570, Y=-4432374.185066, Z=3683167.978451). In the air case, the SUT will create a helicopter at Alder Peak location hovering at 500' AGL (approximate location of X=-2692454.020881, Y=-4416723.773855, Z=3726193.449712).

IST will create one entity of its choice at least 1000 meters from the SUT entity. The IST will maneuver toward the SUT's vehicle until it is close enough to use its weapon of choice. Once in a position to open fire, IST will do so in an attempt to achieve a kill.

IST will record the exercise using its data logger and will verify that Entity Appearance bit was set within 15 seconds. Acceptability will be mutually determined by IST and the SUT. Visualization may also be used if available at either site (i.e., IST or SUT sites).

4.3.1.2 Entity Marking Validation

A validation test for entity marking is not required for the Interoperability Demonstration.

4.3.1.3 Entity Capability Validation

A validation test for entity capability is not required for the Interoperability Demonstration.

4.3.1.4 Articulated Parts Validation

This test is only applicable for entities with articulated parts. Position an entity anywhere on the terrain . Move each articulated part to its maximum position, return to neutral, and then to its minimum position. Any rate of movement is acceptable. For rotating parts without a maximum excursion, perform the following test. Turn the turret clockwise 3 revolutions. Turn the turret counter-clockwise 3 revolutions. Raise the gun to its maximum elevation, then lower it to its minimum elevation 3 times. Record the PDUs generated by these movements. IST will examine a time history of the articulation fields.

5 INTERACTIVITY TESTS

These tests verify that the SUT interacts appropriately with the rest of the simulation by generating events appropriately or by responding properly to externally generated events. These tests will be performed in both Transmission and Reception modes.

5.1 Maneuver, Shoot, Kill

In order to accommodate the diversity of simulators to be tested, the operator of the SUT may choose to interact with a ground, surface, or air entity in the tests described below.

5.1.1 Stationary

In the ground case, IST will create a stationary and harmless vehicle on the ground at Lockwood Post Office (approximate location of X=-2669926.874155, Y=-4428900.674144, Z=3720707.134921). In the surface case, IST will create a ship at anchor(approximate location X=-2716162.393570, Y=-4432374.185066, Z=3683167.978451). In the air case, IST will create a helicopter at Alder Peak location hovering at

500' AGL (approximate location of X=-2692454.020881, Y=-4416723.773855, Z=3726193.449712).

The SUT will create one entity of its choice at least 1000 meters from the IST entity. The SUT will maneuver toward IST's vehicle until it is close enough to use its weapon of choice. Once in position to open fire, the SUT will do so in an attempt to achieve a kill.

IST will record the exercise using its data logger and will verify that Entity State, Fire, and Detonation PDUs were produced at appropriate times. IST will also verify that the SUT entity's velocity vector and position updates are in the general direction of the IST entity and that relevant articulated parts (e.g., turrets and guns) move in a direction toward the IST entity. Acceptability will be mutually determined by IST and the SUT. Visualization may also be used if available at either site (i.e., IST or SUT sites).

5.1.2 Moving

A test of interaction with a moving target will be conducted in a manner similar to that of 5.1.1 above except that the targets will maneuver in a closed loop on the ground, on the surface, or in the air. The vehicles shall all move in circular patterns. The center of rotation shall be at the locations noted in 5.1.1, above for each entity type. The radius of rotation, and velocity, in a parallel plane consistent with each vehicle shall be as follows:

- Helicopter.	Radius=500 meters	velocity=30m/s
- Ground Veh.	Radius=100 meters	velocity=2m/s
- Ship	Radius=2000meters	velocity=6m/s

5.2 Collisions

IST will provide an entity to be used as the target for a collision to be generated intentionally.

5.2.1 Collision with a Stationary Vehicle

IST will create the target entity as in section 5.1.1 above. The SUT will create its entity as before and will then maneuver it to cause a collision with IST's entity.

IST will record the exercise and will verify that a valid Collision PDU is produced by the SUT. IST will attempt to

determine that a consistent collision has occurred between entitites (i.e., elastic or inelastic based upon conservation of momentum). Visual verification of the collision will also be conducted, if feasible.

5.2.2 Collision with a Moving Vehicle

A test of collision with a moving target will be conducted in a manner similar to that of 5.2.1 above except that the target will travel in a circular path at a constant linear and angular velocity. If on the ground, it will conform to the surface. If on the surface, the entity will follow the terrain. If in the air, the entity will maintain constant elevation of 100 meters AGL.

IST will record the exercise and will verify that a valid Collision PDU is produced by the SUT. IST will attempt to determine that a consistent collision has occurred between entitites (i.e., elastic or inelastic based upon conservation of momentum). Visual verification of the collision will also be conducted, if feasible.

5.2.2.1 Collision with Articulated Parts

A test of collision with an entity's articulated part will be conducted in a manner similar to that of 5.2.2 above. The collision test will be performed for three positions of the articulated part: maximum position, minimum position, and neutral position. IST will observe the position of the entity at the collision point, as well as if the collision is elastic or inelastic.

5.3 Manned Simulator Interaction (Qualitative Testing)

IST shall conduct interactive tests using its M-1 simulators with operators in the loop. The purpose shall be to make qualitative assessments regarding interoperability and to identify any problems which quantitative testing may have missed. The identification and resolution of problems shall be determined mutually by IST and the SUT.

5.4 Other Tests

IST may perform other tests if deemed technically feasible, beneficial to determining interoperability, and mutually agreeable to all parties concerned. Currently, additional tests envisioned include testing of Sections 3, 4, 5.1 and 5.2 on a simplified version of a terrain data base.

6 SPECIAL TESTS

6.1 System Loading

IST will present the SUT with a continual increase in PDU's (both broadcast and point to point) up to a load representing 200 entities, if possible. The SUT shall proceed along a course as outlined in Section 3.1, above (repeating the route until conclusion of this test). The purpose will be to observe the PDU type and quantity from the SUT and to discern, visually and analytically (through frequency analysis of PDU type) the ability of the SUT to handle (or ignore) heavy network traffic.

APPENDIX E

TEST PROCEDURES (REDUCED SCOPE VERSION)

Validation Tests
1992 I/ITSC Interoperability Demonstration
(REDUCED SCOPE VERSION)

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0 INTRODUCTION

The purpose of this document is to define the interoperability requirements for participating in the Distributed Interactive Simulation (DIS) Interservice/Industry Training Systems Conference (I/ITSC) interoperability demonstration. The level of interoperability defined is for this demonstration only and does not constitute conformance with the DIS standards for other applications.

0.1 Scope and Criteria

0.1.1 Scope

The tests described in this document are performed under the following set of assumptions:

Network Protocols. Each System Under Test (SUT) is required to be able to connect to and communicate with an Ethernet network. In addition, SUTs are required to use the User Datagram Protocol/Internet Protocol (UDP/IP). If the SUT is sending information on the network, it should be able to utilize the UDP/IP/Ethernet protocols to send and receive information. If the SUT is only receiving information from the network, it should be able to interpret UDP/IP/Ethernet protocols. DIS PDUs will be sent using broadcast mode. Non-DIS information will be sent using point-to-point services.

Application Messages. Each SUT is required to be able to interpret a subset of the DIS Protocol Data Units (PDUs) as defined in the May 8, 1992 draft of "Protocol Data Units for Entity Information and Entity Interaction in a Distributed Interactive Simulation", IST report IST-PD-91-1. The required PDUs are: Entity State, Weapons Fire, Detonation, and Collision. This document will verify that the above noted Protocol Data Units are correct with respect to syntax and consistent with respect to interpretation and utilization by a simulator. SUTs which send information on the network should be able to correctly build the appropriate PDUs according to the rules found in the DIS PDU standard. SUTs which only receive information should be able to correctly interpret the DIS PDUs.

Terrain, Feature, and Model Information. Each SUT is required to use the Project 2851 SIF data provided by the U.S. Air Force and PRC for development of terrain, feature, and dynamic entity models for use in the demonstration. Correlation of various terrain databases developed from the SIF data must be within specified limits for participation in the demo.

0.1.2 Criteria

Criteria refers to the standards upon which judgements are made. With respect to this document, criteria are the quantity of tests which must be successfully completed for a system to be judged interoperable. Criteria must, therefore, be consistent with the scope in a general sense and the specific tests (enumerated below) in precise terms. A simulator must meet all of the detailed requirements which follow to satisfactorily meet the criteria of interoperability associated with the I/ITSC demonstration.

0.2 Graduated Testing

0.2.1 Rationale

Validation testing is divided into a sequence of levels in an attempt to isolate problems in the System Under Test (SUT) at the lowest possible level. The tests proceed from basic communications tasks upward through progressively higher-order behavior.

The first test verifies that the SUT can transmit and receive information on the network using the UDP/IP/Ethernet protocols. Once communication is established, the SUT will be tested to ensure that the PDUs generated are correct with respect to syntax and consistent with respect to interpretation. The third test demonstrates that an entity is capable of moving around the terrain. The last test verifies that the entity can interact with other entities on the terrain.

0.2.2 Organization of the Test Levels

NETWORK LEVEL TESTS focus on verifying the ability to transmit and receive data packets using UDP/IP/Ethernet.

PDU TESTS verify the bi-directional exchange of Application Level Messages (PDUs) generated or interpreted by the SUT.

TERRAIN ELEVATION COMPARISON TESTS verify correlation between the Terrain Database (TDB) used by the SUT and a reference TDB.

APPEARANCE, LOCATION AND ATTITUDE TESTS verify proper generation and interpretation of location, orientation, and velocity information.

INTERACTIVITY TESTS verify that the SUT interacts appropriately with the rest of the simulation by generating events appropriately or by responding properly to externally generated events.

0.2.3 Test Modes

For each of the test levels described above, there are two modes of testing:

Transmission Test - SUT sends data, IST receives data

Reception Test - IST sends data, SUT receives data.

In Transmission mode, IST will verify that the SUT can generate and transmit the required data and will determine if the SUT has successful completed the test. In Reception mode, the SUT will be responsible for verifying that it is capable of receiving the IST generated information. Further analysis of the IST data is encouraged, not required.

SUTs that will be transmitting and receiving data (i.e., CGF and manned simulators) will be required to pass both Transmission and Reception tests. SUTs that will not be transmitting data (e.g., stealth, radar displays) will be required to pass the Reception Tests only.

0.3 Test Methods

The tests described in this document will be conducted by using either an IST supplied PC-based data logger or a dial-up facility provided by IST. Due to the limited bandwidth available (9600 baud) for the dial-up method, the prefered method of testing is the PC-based data logger. These two testing methods are described below.

0.3.1 Data Logger Method

For demonstration participants who have assembled a PC-based Data Logger at their site, files will be provided containing data packets for accomplishing the required interoperability tests. These files may be obtained via Internet electronic mail or on floppy disk (5 1/4" or 3 1/2" high density).

Tests that require the SUT to receive information (i.e., Reception Tests) for correct interpretation would utilize the Data Logger to issue pre-recorded packets found in the test files. Tests that require that the SUT send information to the IST test system (i.e., Transmission Tests) would utilize the Data Logger to record the information. This recorded data would be sent to IST for review using either of the above mentioned methods.

0.3.2 Dial-Up Method

Participants who do not have a PC-based Data Logger may conduct the tests described above using an extended Ethernet LAN implemented via a toll-free telephone link provided by IST. IST will record packets produced by the SUT and will play pre-recorded files when transmitting.

The SUT will need to use the Serial Line Internet Protocol (SLIP) or the Point to Point Protocol (PPP) for serial communications via the telephone link. Testing in this fashion will require coordination with IST via a separate voice connection.

1 NETWORK LEVEL TESTS

Specifying the appropriate addressing structures and data length fields is a prerequisite to being able to exchange DIS PDU's. Network Level Tests verify that the player can generate and interpret these addresses and the data lengths for the UDP/IP/Ethernet communication protocols.

Of necessity, some other checks must be performed; e.g. a limited check for byte ordering is implicit in examining the content of protocol header fields which are greater than one octet in length.

This is not a conformance test of the UDP/IP/Ethernet protocols; it is a test of only those fields which are important to the transfer of DIS PDUs, namely addressing and

data. Data integrity calculations, i.e. checksums, will not be checked other than to determine if the transmitted data has been corrupted. If the data has been corrupted, it will be discarded.

1.1 Broadcast Test

The SUT must demonstrate the capability to send and receive, in broadcast mode, UDP/IP/Ethernet packets in order to achieve interoperability in the I/ITSC Interoperability Demonstration. Testing this capability will be done in two steps. The first step is to test the SUTs ability to build and broadcast UDP/IP/Ethernet packets. The second step is to verify the SUTs ability to receive and interpret such data. The tests are described in the paragraphs that follow.

1.1.1 Transmission Test

To test broadcast transmission, as will be used in the Interoperability Demonstration to transmit DIS PDUs, the SUT will generate and transmit a packet whose data will be a Fire PDU. IST will capture the packet and verify correctness of the player's UDP, IP, and Ethernet header frames for the following fields: destination address, protocol address, data length, and data content.

<u>Destination Address</u> - Only destination addresses will be tested because DIS does not care where the data originates. These fields are found in the Ethernet and IP header frames.

<u>Protocol Address</u> - There are only three protocols (above the physical interface) to be used, viz. IP, UDP and DIS. Each protocol is identified in the preceding lower layer by a unique number. If these numbers are not used, the PDU will not reach the simulation destination. The tests will be conducted for both valid and invalid protocol numbers.

<u>Data Length</u> - At each layer of the communication stack, the PDU is encapsulated in protocol headers. In each protocol, the data length field represents the total size of the data (i.e., data + header) for that layer. The data length is represented in octets. The test will determine if the appropriate length is calculated for the Fire PDU.

Succesful completion of these tests shall be achieved if the SUT can generate and interpret destination addresses, protocol addresses, and data lengths for the test method in use.

1.1.1.1 Fields of Concern

Except where indicated by a prefix of 0x to indicate base 16 (hexadecimal), decimal values are specified below for all fields of concern. IST will verify that the correct values appear in all fields.

Destination Address

Ethernet Dest Address	=	255-255-255-255-255-255 (all bits set TRUE)
IP Destination Address	=	132.170.255.255

Protocol Address

Ethernet Type Field	=	6 // IP
IP Protocol Field	=	17 // UDP
UDP Port Number	=	3000 // DIS Application

Data Length

IP Length Field	=	20 (IP length) + 8 (UDP length) + length of UDP data in octets
UDP Length Field	=	8 (UDP length) + length of UDP data in octets

1.1.1.2 Sample Frame

In all cases in this document fields marked with DC (Don't Care) will not be checked.

<u>Ethernet Frame</u>

preamble	=	DC
start frame delim.	=	DC
dest. address	=	255-255-255-255-255-255
source address	=	DC
type	=	0x0800

IP Frame

version	=	4
IHL	=	DC
type of service	=	DC
total length	=	20 (IP length in octets) + 8 (UDP length in octets) + length (in octets) of UDP data
identification	=	DC
fragmentation offset	=	0
time to live	=	DC
protocol	=	17
header checksum	=	DC
source address	=	DC
dest. address	=	132.170.255.255

UDP Frame

source port	=	DC
dest. port	=	3000
length	=	8 (UDP length in octets) + length (in octets) of UDP data
checksum	=	DC
data	=	Fire PDU

1.1.2 Reception Test

To test the SUT's ability to receive UDP/IP/Ethernet packets, the IST test system will generate and transmit (in broadcast mode) the packet defined in 1.1.1.2 above. It is the responsibility of the SUT to verify that it receives the entire packet and interprets all fields correctly.

1.2 Point-to-Point Test

In the case where the SUT intends to use the I/ITSC interoperability network for non-DIS traffic, it is required that the information be sent using a unicast service (also called point-to-point). In this case, the SUT must demonstrate its ability to use this network service in order to be interoperable for the I/ITSC demo.

Because point-to-point traffic will be generated by demo participants, SUTs must expect such data and should be able to receive and subsequently reject such data without adverse affect on the SUT or the network. Demo participants not using the point-to-point services are still required to pass the point-to-point reception tests (see 1.2.3). SUTs that will be using point-to-point services (those sending non-DIS traffic)

on the I/ITSC demo network are required to pass all tests described in this section.

As in the broadcast testing there are two steps to testing point-to-point network usage. The first step is to test the SUTs ability to build and transmit UDP/IP/Ethernet packets using point-to-point services. The second step is to verify the SUTs ability to receive and interpret such data. These tests, performed for the Dial-Up method only, are described in the paragraphs that follow.

1.2.1 Address Resolution Protocol (ARP)

In addition to the capability of sending and receiving information, the SUT must be able to implement ARP in order to obtain physical address information. In the point-to-point transmission test, the SUT will be given the IP address for the IST test system. Using the supplied IP address, the SUT must broadcast an ARP Request to the network. The IST system, recognizing the IP address, will respond to the ARP request with an ARP reply containing the Ethernet address of the IST test system. This Ethernet address will be used to establish point-to-point communications with the IST test system.

Similarly, in the point-to-point reception test, the SUT will supply the IST test system with its IP address. The IST test system will issue an ARP Request to the SUT supplied IP address. The SUT, recognizing its IP address, should respond with an ARP reply containing its Ethernet address. This Ethernet address will be used by the IST test system for point-to-point communications.

1.2.2 Transmission Test

To test point-to-point transmission, as will be used in the Interoperability Demonstration to transmit non-DIS data, the SUT will generate and transmit a packet whose data will be an example of the non-DIS data the participant will generate. IST will capture the packet and verify correctness of the player's UDP, IP, and Ethernet header frames for the following fields: destination address, protocol address, data length, and data content.

Succesful completion of these tests shall be achieved if the SUT can both generate and interpret destination addresses, protocol addresses, and data lengths for the test method in use.

1.2.2.1 Fields of Concern

Except where indicated by a prefix of 0x to indicate base 16 (hexadecimal), decimal values are specified below for all fields of concern. IST will verify that the correct values appear in all fields.

Destination Address

Ethernet Dest Address	=	xxx-xxx-xxx-xxx-xxx-xxx (determined by ARP)
IP Destination Address	=	xxx.xxx.xxx.xxx (tbd at time of test)

Protocol Address

Ethernet Type Field	=	6 // IP
IP Protocol Field	=	17 // UDP
UDP Port Number	=	3000 // DIS Application

Data Length

IP Length Field	=	20 (IP length) + 8 (UDP length) + length of UDP data in octets
UDP Length Field	=	8 (UDP length) + length of UDP data in octets

1.2.2.2 Sample Frame

In all cases in this document fields marked with DC (Don't Care) will not be checked.

<u>Ethernet Frame</u>

preamble	=	DC
start frame delim.	=	DC
dest. address	=	xxx-xxx-xxx-xxx-xxx-xxx (determined by ARP)
source address	=	DC
type	=	0x0800

<u>IP Frame</u>

version	=	4
IHL	=	DC
type of service	=	DC
total length	=	20 (IP length in octets) + 8

		(UDP length in octets) + length (in octets) of UDP data
identification	=	DC
fragmentation offset	=	0
time to live	=	DC
protocol	=	17
header checksum	=	DC
source address	=	DC
dest. address	=	xxx.xxx.xxx.xxx (tbd at time of test)

UDP Frame

source port	=	DC
dest. port	=	3000
length	=	8 (UDP length in octets) + length (in octets) of UDP data
checksum	=	DC
data	=	non-DIS data

1.2.3 Reception Test

To test the SUT's ability to receive UDP/IP/Ethernet packets, the IST test system will generate and transmit (in point-to-point mode) the packet defined in 1.2.2.2. It is the responsibility of the SUT to verify that it receives the entire packet and discards it appropriately.

2 PDU TESTS

PDU Tests will be conducted to determine whether the SUT can build and interpret the Application Level Data structures defined by the DIS 1.0 Standard. Both Transmission and Reception tests will be conducted for each of the four required PDU types.

PDUs will be built using the values as specified in this section except where indicated. Values to be placed in fields marked "selected by SUT" will be provided at the time of the test by the operator of the SUT. The intent of the tests is to verify alignment, byte ordering, data types, etc.

The number of articulation parameters in the Entity State PDU or Detonation PDU is indicated in the # OF ARTICULATION PARAMETERS (numPar) field. If the value of the numPar field is zero, the PDU is 1152 bits in length. If the value of the numPar field is greater than zero, this indicates how many ARTICULATION PARAMETERS the PDU carries, and the PDU is (1152 + 128 * numPar) bits long.

During Transmission Tests, IST will verify that the correct values appear in all the fields. If discrepancies arise, IST will attempt to determine the cause (e.g. byte ordering reversed, field not initialized, etc.).

During Reception Tests, the developer will verify that all fields are interpreted as intended.

Succesful completion of these tests shall be achieved if the SUT can transmit and receive each of the four required PDU types.

2.1 Entity State PDU

```
// PDU HEADER

header.version                  = 0x01
header.exercise                 = 0x01
header.kind                     = 0x01      // EntityState
header.unused_8                 = DC

// ENTITY ID

entityID.simulator.site         = selected by SUT
entityID.simulator.host         = selected by SUT
entityID.entity                 = selected by SUT

// VARIOUS DESCRIPTIVE FIELDS...

unused_8                        = DC
forceID                         = 0x1      //BLUE FORCE
entityType                      = selected by SUT

// guise should be 0 when unused

guise.entityKind                = 0x00
guise.domain                    = 0x00
guise.country                   = 0x00
guise.category                  = 0x00
guise.sub_category              = 0x00
guise.specific                  = 0x00
guise.extra                     = 0x00

// Standard says this is a 32 bit unsigned integer but least
// significant bit is a flag to indicate absolute or relative
// Therefore, mask out the low-order bit, then divide the high
// 31 bits by 2 to get the value.
```

```
timeStamp                              = DC

// Entity Location, Velocity, and Orientation

location.x                             = selected by SUT
location.y                             = selected by SUT
location.z                             = selected by SUT
velocity.x                             = selected by SUT
velocity.y                             = selected by SUT
velocity.z                             = selected by SUT
orientation.psi                        = selected by SUT
orientation.theta                      = selected by SUT
orientation.phi                        = selected by SUT


// Dead Reckoning Parameters

deadReckonParms.algorithm              = 0x02    // use
                                                 DRM(F,P,W)
                                                 scheme

deadReckonParms.unused_8               = DC
deadReckonParms.unused_16              = DC
deadReckonParms.unused_32              = DC
deadReckonParms.unused_32_2            = DC
deadReckonParms.unused_32_3            = DC

deadReckonParms.acceleration.x         = DC
deadReckonParms.acceleration.y         = DC
deadReckonParms.acceleration.z         = DC

deadReckonParms.angularVelocity.x      = DC
deadReckonParms.angularVelocity.y      = DC
deadReckonParms.angularVelocity.z      = DC

// Appearance; All platforms (but not Life forms or
// Environmentals) can be depicted as DESTROYED so we'll
// set only that bit.

appearance                             = 0x00000001 //Destroyed


marking.characterSet                   = 0x01    //ASCII

marking.text                           = DC
```

```
// Does DIS Standard say what these capabilities mean?
// Assume it means that the entity can SUPPLY ammo or
// fuel or miscellaneous supplies or repairs TO OTHER
// ENTITIES.

capabilities                        = DC

// Padding

unused_16_2                         = DC
unused_8_2                          = DC

// Articulated Parts Array Size for Ground Vehicles Only

numParts                            = selected by SUT
                                    // either 0 or 2

     // First record if numParts = 2
     // Not present if numParts = 0

parts[0].change                     = selected by SUT
parts[0].partID                     = selected by SUT
parts[0].numberParms                = selected by SUT
parts[0].partsParms                 = selected by SUT

     // Second record if numParts = 2
     // Not present if numParts = 0

parts[1].change                     = selected by SUT
parts[1].partID                     = selected by SUT
parts[1].numberParms                = selected by SUT
parts[1].partsParms                 = selected by SUT
```

2.2 Fire PDU

```
// PDU HEADER

header.version                      = 0x01
header.exercise                     = 0x01
header.kind                         = 0x02    // Fire
header.unused_8                     = DC

// ID of firing entity

attackerID.simulator.site           = selected by SUT
attackerID.simulator.host           = selected by SUT
attackerID.entity                   = selected by SUT
```

```
// ID of intended target, arbitrary

targetID.simulator.site              = selected by SUT
targetID.simulator.host              = selected by SUT
targetID.entity                      = selected by SUT


// If this is a munition that must be flown, it needs a valid
// ID.  Otherwise all three munition fields must be set to
// zero for the "INVALID" ID.

munitionID.simulator.site            = selected by SUT
munitionID.simulator.host            = selected by SUT
munitionID.entity                    = selected by SUT

eventID.simulator.site               = selected by SUT
eventID.simulator.host               = selected by SUT
eventID.event                        = selected by SUT

// a value of 0 time units, relative scheme

timeStamp                            = selected by SUT

// Launch Location

location.x                           = selected by SUT
location.y                           = selected by SUT
location.z                           = selected by SUT

burst.munition                       = selected by SUT
burst.warhead                        = selected by SUT
burst.fuze                           = selected by SUT
burst.quantity                       = selected by SUT
burst.rate                           = selected by SUT

velocity.x                           = selected by SUT
velocity.y                           = selected by SUT
velocity.z                           = selected by SUT
range                                = selected by SUT
```

2.3 Detonation PDU

```
// PDU HEADER

header.version                       = 0x01
header.exercise                      = 0x01
header.kind                          = 0x03     // Detonation
header.unused_8                      = DC
```

```
// ID of firing entity

attackerID.simulator.site           = selected by SUT
attackerID.simulator.host           = selected by SUT
attackerID.entity                   = selected by SUT

// ID of intended target (arbitrary)

targetID.simulator.site             = selected by SUT
targetID.simulator.host             = selected by SUT
targetID.entity                     = selected by SUT

// Make this a munition that must be flown, it needs a valid
// ID.  Otherwise all three munition fields must be set to
// zero for the "INVALID" ID.

munitionID.simulator.site           = selected by SUT
munitionID.simulator.host           = selected by SUT
munitionID.entity                   = selected by SUT

eventID.simulator.site              = selected by SUT
eventID.simulator.host              = selected by SUT
eventID.event                       = selected by SUT

// a value of x time units, relative scheme

timeStamp                           = selected by SUT

worldLocation.x                     = selected by SUT
worldLocation.y                     = selected by SUT
worldLocation.z                     = selected by SUT

burst.munition                      = selected by SUT
burst.warhead                       = selected by SUT
burst.fuze                          = selected by SUT
burst.quantity                      = selected by SUT
burst.rate                          = selected by SUT
velocity.x                          = selected by SUT
velocity.y                          = selected by SUT
velocity.z                          = selected by SUT

entityLocation.x                    = selected by SUT
entityLocation.y                    = selected by SUT
entityLocation.z                    = selected by SUT
result                              = selected by SUT

numParts                            = 0
```

2.4 Collision PDU

```
// PDU HEADER

header.version                  = 0x01
header.exercise                 = 0x01
header.kind                     = 0x04    // Collision
header.unused_8                 = DC

issueID.simulator.site          = selected by SUT
issueID.simulator.host          = selected by SUT
issueID.entity                  = selected by SUT

collideID.simulator.site        = selected by SUT
collideID.simulator.host        = selected by SUT
collideID.entity                = selected by SUT

eventID.simulator.site          = selected by SUT
eventID.simulator.host          = selected by SUT
eventID.event                   = selected by SUT

unused_16                       = DC

// a value of 16 time units, relative scheme

timeStamp                       = selected by SUT

velocity.x                      = selected by SUT
velocity.y                      = selected by SUT
velocity.z                      = selected by SUT

mass                            = selected by SUT
location.x                      = selected by SUT
location.y                      = selected by SUT
location.z                      = selected by SUT
```

3 TERRAIN ORIENTATION COMPARISION TESTS

This test is applicable to entities which operate on or in close proximity to the terrain or ocean surface. Correlation is necessary for successful interoperability since each participant will have separately converted the terrain database supplied by Project 2851. This test will be performed in Transmission mode only.

Note: all coordinates given for the remainder of the test plan are computed on the following assumption. Southwest corner of the Hunter Ligget database:

geodetic:	N 35 deg 15'	W 122 deg 4'	0
UTM:	E 584909.6	N 3901166.8	0

3.1 Orientation Transmission Tests

IST will receive Entity State PDU's based upon the following conditions.

An air entity being simulated will follow the following course. Starting at position:

	EQ 94 11
UTM (source):	E 594909.6 N 3911166.8 10000 alt.
geocentric (derived):	X=-2761110.1, Y=-4426326.8, Z=3674417.9
geodetic (derived):	N 35 deg. 20' 21.3" W 121 deg. 57' 20.2" 10000 alt.

Proceed North, at a constant speed and orientation relative to sea level, along a straight line course toward:

	EQ 94 21
UTM (source):	E 594909.6 N 3921166.8 10000 alt.
geocentric (derived):	X=-2757949.3, Y=-4421460.3, Z=3682586.7
geodetic (derived):	N 35 deg. 25' 45.9" W 121 deg. 57' 16" 10000 alt.

A ground entity being simulated will start at position:

	FQ 70 80
UTM (source):	E 670000 N 3980000 298 alt.
geocentric (derived):	X=-2671397.8, Y=-4425792, Z=3723839.4
geodetic (derived):	N 35 deg. 56' 58.5" W 121 deg. 6' 54.3" 298 alt.

Proceed toward the Lockwood Post Office on a bearing of 125 degrees from North clockwise. Attempt to maintain a constant speed.

A sea entity being simulated will start at position:

	EQ 94 11
UTM (source):	E 594909.6 N 3911166.8 0 alt.
geocentric (derived):	X=-2756792.7, Y=-4419405.6, Z=3668633.8
geodetic (derived):	N 35 deg. 20' 21.3" W 121 deg. 57' 20.2" 0 alt.

Proceed North, at a constant speed along a straight line course toward:

	EQ 94 21
UTM (source):	E 594909.6 N 3921166.8 0 alt.
geocentric (derived):	X=-2753636.9, Y=-4414546.8, Z=3676789.7
geodetic (derived):	N 35 deg. 25' 45.9" W 121 deg. 57' 16" 0 alt.

Ground, sea, and air entities shall follow the specific course as described above. IST will make at least three samplings (at points chosen by IST, but not revealed to the SUT) of Entity State PDUs. IST will examine the position, velocity, and time stamps to verify internal consistency in the PDUs. Visual observation will also be made of this test to note any anomalies not detected in the analytical data. In the case of ground vehicles, IST recognizes that course maneuvering will be required to avoid obstacles. This will be taken into account.

4 APPEARANCE TESTS

Tests in this section are intended to validate the algorithms used by the SUT to determine and interpret location, attitude, and velocity information, position of articulated parts, and special appearance indications. Tolerances are stated and are subject to adjustment.

4.1 Location and Attitude Tests

Tests in this section shall be made to determine proper interpretation of location and orientation structures used in entity state PDUs. Only the Entity State PDU is used for this section of tests. The Protocol Version, Exercise Identifier, Padding, Entity ID, ForceID, and Entity Type fields are not explicitly evaluated on this set of tests; however, their values must be correct for viewing and tracking purposes (see section 2.1). Unless stated otherwise, all velocities and accelerations shall be equal to zero. These tests will be performed in both Transmission and Reception modes.

4.1.1 Location Tests

Tests in this section ensure that the Entity Location is interpreted uniformly between simulators. The Entity Location and time stamp fields of the Entity State PDU are the primary fields studied in this section.

For ground entities, the SUT shall position a stationary entity on the terrain surface at:

	FQ 70 80
UTM (source):	E 670000 N 3980000 298 alt.
geocentric (derived):	X=-2671397.8, Y=-4425792, Z=3723839.4
geodetic (derived):	N 35 deg. 56' 58.5" W 121 deg. 6' 54.3" 298 alt.

Sea entities shall be positioned at:

	EQ 94 11
UTM (source):	E 594909.6 N 3911166.8 0 alt.
geocentric (derived):	X=-2756792.7, Y=-4419405.6, Z=3668633.8
geodetic (derived):	N 35 deg. 20' 21.3" W 121 deg. 57' 20.2" 0 alt.

A helicopter should hover at:

	EQ 94 11
UTM (source):	E 594909.6 N 3911166.8 1000 alt.
geocentric (derived):	X=-2757224.4, Y=-4420097.7, Z=3669212.2
geodetic (derived):	N 35 deg. 20' 21.3" W 121 deg. 57' 20.2" 1000 alt.

In the case of a jet, the scenario will be mutually determined by IST and the SUT.

The SUT shall then send Entity State PDUs for a period of one minute. IST will check the resulting PDUs to verify that the location of the entity (origin) is within 1 meter (tolerance) of the designated position and that PDUs are transmitted at a rate of approximately .2 Hz.

4.1.2 Attitude Tests

Tests in this section shall be made to validate consistent interpretation of axis system orientation in the DIS Standard. Tests in this section primarily use the Entity Orientation field of the Entity State PDU.

For ground entities, the SUT shall position an entity on the terrain surface at:

	FQ 70 80
UTM (source):	E 670000 N 3980000 298 alt.
geocentric (derived):	X=-2671397.8, Y=-4425792, Z=3723839.4
geodetic (derived):	N 35 deg. 56' 58.5" W 121 deg. 6' 54.3" 298 alt.

Proceed North for approximately 10 seconds, make a 720 degree right turn, proceed North for approximately 10 seconds. Then make a 90 degree left turn.

Sea entities shall be positioned at:

	EQ 94 11
UTM (source):	E 594909.6 N 3911166.8 0 alt.
geocentric (derived):	X=-2756792.7, Y=-4419405.6, Z=3668633.8
geodetic (derived):	N 35 deg. 20' 21.3" W 121 deg. 57' 20.2" 0 alt.

Proceed North for approximately 10 seconds, make a 720 degree right turn, proceed North for approximately 10 seconds. Then make a 90 degree left turn.

Air vehicles shall fly through:

	EQ 94 11
UTM (source):	E 594909.6 N 3911166.8 10000 alt.
geocentric (derived):	X=-2761110.1, Y=-4426326.8, Z=3674417.9
geodetic (derived):	N 35 deg. 20' 21.3" W 121 deg. 57' 20.2" 10000 alt.

Proceed North for approximately 10 seconds, make a 720 degree right hand turn, fly North for approximately 10 seconds, make a 90 degree left hand turn. Then, if possible, make a barrel roll and an inside loop, steady up and head West straight and level.

Acceptability will be mutually determined by IST and the SUT. Visualization may also be used if available at either site (i.e., IST or SUT sites).

4.2 Dead Reckoning Validation

This section will build upon tests conducted in 4.1, above to test the consistency between a simulator's representation of linear velocity, orientation, and other dead reckoning parameters. These tests will be performed in both Transmission and Reception modes.

4.2.1 Linear Velocity Validation

IST will examine adajacent pairs of Entity State PDUs from the test in Section 3.1 and hand calculate location based on velocity and time stamp fields. Acceptability is determined by a location accurate to within 1 centimeter (tolerance).

4.2.2 Angular Velocity Validation

A validation test for angular velocity is not required for the Interoperability Demonstration.

4.2.3 Linear Acceleration Validation

A validation test for linear acceleration is not required for the Interoperability Demonstration.

4.3 Appearance Validation

This set of tests shall verify the proper use of Entity Type, Entity Appearance, Entity Marking, Capabilities, # Articulation Parameters, and Articulation Parameters fields in the Entity State PDU.

4.3.1 Entity Type Validation

The SUT will be required to send Entity State PDUs for each of the entities that it can generate. If the SUT has an image generator, IST will send each of the entity types listed in the IST Entity Type Sheet of 6/4/92. The SUT will be required to display each of these entity types. If the SUT does not have an image generator, the recognizition of entity types will be mutually determined by IST and the SUT.

4.3.1.1 Entity Appearance Validation

A validation test for entity appearance will be conducted as part of the test specified 5.1.

4.3.1.2 Entity Marking Validation

A validation test for entity marking is not required for the Interoperability Demonstration.

4.3.1.3 Entity Capability Validation

A validation test for entity capability is not required for the Interoperability Demonstration.

4.3.1.4 Articulated Parts Validation

This test is only applicable for entities with articulated parts. Position an entity anywhere on the terrain. Move each articulated part to its maximum position, return to neutral,

and then to its minimum position. Any rate of movement is acceptable. For rotating parts without a maximum excursion, perform the following test. Turn the turret clockwise 3 revolutions. Turn the turret counter-clockwise 3 revolutions. Raise the gun to its maximum elevation, then lower it to its minimum elevation 3 times. Record the PDUs generated by these movements. IST will examine a time history of the articulation fields.

5 INTERACTIVITY TESTS

These tests verify that the SUT interacts appropriately with the rest of the simulation by generating events appropriately or by responding properly to externally generated events. These tests will be performed in both Transmission and Reception modes.

5.1 Maneuver, Shoot, Kill

In order to accommodate the diversity of simulators to be tested, the operator of the SUT may choose to interact with a ground, surface, or air entity in the tests described below. The SUT will be required to complete either the Stationary or the Moving test (not both) as described below.

5.1.1 Stationary

In the ground case, IST will create a stationary and harmless vehicle on the ground at Lockwood Post Office:

	FQ 70 80
UTM (source):	E 670000 N 3980000 298 alt.
geocentric (derived):	X=-2671397.8, Y=-4425792, Z=3723839.4
geodetic (derived):	N 35 deg. 56' 58.5" W 121 deg. 6' 54.3" 298 alt.

In the surface case, IST will create a ship at anchor:

	EQ 94 11
UTM (source):	E 594909.6 N 3911166.8 0 alt.
geocentric (derived):	X=-2756792.7, Y=-4419405.6, Z=3668633.8
geodetic (derived):	N 35 deg. 20' 21.3" W 121 deg. 57' 20.2" 0 alt.

In the air case, IST will create a helicopter at:

	EQ 94 11
UTM (source):	E 594909.6 N 3911166.8 1000 alt.
geocentric (derived):	X=-2757224.4, Y=-4420097.7, Z=3669212.2
geodetic (derived):	N 35 deg. 20' 21.3" W 121 deg. 57' 20.2" 1000 alt.

The SUT will create one entity of its choice at least 1000 meters from the IST entity. The SUT will maneuver toward IST's vehicle until it is close enough to use its weapon of choice. Once in position to open fire, the SUT will do so in an attempt to achieve a kill.

IST will record the exercise using its data logger and will verify that Entity State, Fire, and Detonation PDUs were produced at appropriate times. IST will also verify that the SUT entity's velocity vector and position updates are in the general direction of the IST entity and that relevant articulated parts (e.g., turrets and guns) move in a direction toward the IST entity. In addition, IST will verify that the Entity Appearance destroyed bit is set within 15 seconds after a destructive fire. Acceptability will be mutually determined by IST and the SUT. Visualization may also be used if available at either site (i.e., IST or SUT sites).

5.1.2 Moving

A test of interaction with a moving target will be conducted in a manner similar to that of 5.1.1 above except that the targets will maneuver in a closed loop on the ground, on the surface, or in the air. The vehicles shall all move in circular patterns. The center of rotation shall be at the locations noted in 5.1.1, above for each entity type.

5.2 Collisions

IST will provide an entity to be used as the target for a collision to be generated intentionally. The SUT will be required to complete either the Stationary or the Moving test (not both) as described below.

5.2.1 Collision with a Stationary Vehicle

IST will create the target entity as in section 5.1.1 above. The SUT will create its entity as before and will then maneuver it to cause a collision with IST's entity.

IST will record the exercise and will verify that a valid Collision PDU is produced by the SUT. Visual verification of the collision will also be conducted, if feasible.

5.2.2 Collision with a Moving Vehicle

A test of collision with a moving target will be conducted in a manner similar to that of 5.2.1 above except that the target will travel in a circular path at a constant linear and angular velocity. If on the ground, it will conform to the surface. If on the surface, the entity will follow the terrain. If in the air, the entity will maintain constant elevation of 100 meters AGL.

IST will record the exercise and will verify that a valid Collision PDU is produced by the SUT. Visual verification of the collision will also be conducted, if feasible.

5.2.2.1 Collision with Articulated Parts

A test of collision with an entity's articulated part will not be required for the I/ITSC demonstration.

5.3 Manned Simulator Interaction (Qualitative Testing)

A test with a manned simulator will not be required for the I/ITSC demonstration.

5.4 Other Tests

IST may perform other tests if deemed technically feasible, beneficial to determining interoperability, and mutually agreeable to all parties concerned. Currently, additional tests envisioned include testing of Sections 3, 4, 5.1 and 5.2 on a simplified version of a terrain data base.

6 SPECIAL TESTS

6.1 System Loading

IST will present the SUT with a continual increase in PDU's (broadcast) up to a load representing 200 "busy" entities, if possible. The SUT shall proceed along a course as outlined in Section 3.1, above (repeating the route until conclusion of this test). The purpose will be to observe the PDU type and quantity from the SUT and to discern, visually and analytically (through frequency analysis of PDU type) the

ability of the SUT to handle (or ignore) heavy network traffic.

Due to the bandwidth limitations of the (800) dial-up communications, this test will be conducted Wednesday morning (November 3) at 11:00.

APPENDIX F

TEST TOOLS
(See Diskette)

APPENDIX G

TEST RESULTS DOCUMENT

TEST RESULTS

Date :______________

Time :______________

IST Tester(s) :____

Name of Company :____

Name of Tester(s):____

....
....

ISF Testbed Version Number:
(upper left hand corner of simulator)

Data Logger Version Number:

Terrain Database:
(SIF or SIMNET Hunter Ligget)

Test Plan Version: REDUCED SCOPE

Simulator Tested (including serial #):

Comments:

NOTES TO THE TESTERS

Analyzing Test Results:
Data will be analyzed in two ways: off-line observation of data logged streams and visual verification. Each test states which method will be used.

Data Logging Results:
All test data should be recorded with the data logger, so remember to turn on the data logger before starting the test. To do this, go to the TEST directory and type "logger <filename>" and turn on both the ".txt" and ".bin" switches by typing "t" and "b". When the test data has been captured, close the test files by typing "t" and "b". The <filename> for each test should begin with the company prefix, followed by the SUT number (if the company has more than one SUT), and the test number. The following list are company prefixes:

Company	Prefix	Company	Prefix
Loral	LOR	Grumman	GRU
TSI	TSI	IST	IST
CAE-Link	CAE	NTSC	NTS
BBN	BBN	Hughes	HUG
Armstrong Labs	ARM	IDA	IDA
Lockheed	LOC	McDonnell Douglas	MCD
IBM	IBM	ECC	ECC
NRaD	NRD	Motorola	MOT
GD Land	GDL	GD Ft. Worth	GDF
Rockwell	ROC	Reflectone	REF
Silicon Graphics	SIG	Concurrent Computer	CON
GE Aerospace	GEA		

Example <filename>: NRD4-511.txt

After each SUT's data has been analyzed, the file should be "zipped" and saved to the company's disk.

Helpful Information:

DIS PDUs have the following octet lengths:
- Entity State (no articulated parts) = 144
- Entity State (with 2 articulated parts) = 176
- Fire = 88
- Detonation = 100
- Collision = 56

Except where indicated by a prefix of 0x to indicate base 16 (hexadecimal), decimal values are specified below for all fields of concern.

1. NETWORK TESTS

This test must be analyzed on the spot. The SUT may not go to the next level of testing without passing this test.

1.1 Broadcast Test

TRANSMISSION

This test is mandatory for simulators/CGF.

Test Name: PrefixSUT#-11.txt or.bin (ex:IST1-11.txt)

Instructions: The SUT should broadcast a FIRE PDU onto the network.

Results:

Protocol Field	Expected Value	SUT Value
preamble	DC	
start frame delim.	DC	
dest. address	FFFFFFFFFFFF	
source address	DC	
type	0x8	
version	4	
IHL	5	
type of service	DC	
total length	28 + 88 = 116	
identification	DC	
fragmen. offset	0	
time to live	DC	
protocol	0x11	
header checksum	DC	
source address	DC	
dest. address	132.170.255.255	
source port	DC	
dest. port	0xBB8 (3000)	
length	8 + 88 = 96	
checksum	DC	
data	FIRE PDU	

RECEPTION TEST

This test is mandatory for Listen Only devices (i.e., stealths, radars, network monitors, etc.) and for simulators/CGF.

Instructions: To perform the Reception test, go the to data logger directory and type "PLAYBACK FIRE.BIN"

Results: Was this test performed? If so, did the SUT receive the data?

Comments:

1.2 Point-to-Point Tests

ARP TEST

This test is mandatory for all SUTs (listen only and simulators/CGF). The purpose of the test is to verify send/receive capability. This test should have already been performed by Gamini, et. al. when establishing the network. If this test can not be passed, it does not constitute exclusion from the demo.

Instructions: To perform the test, go to the TEST directory and type "ATST" for a group ARP or UTST for an individual ARP. A positive response in the group ARP will be indicated by the company's name and IP address (found in the test book) turning blue; a positive response in the individual ARP will be indicated by the message "Reply Received".

Results: Was an ARP test conducted? If so, did the SUT reply?

TRANSMISSION TEST

This test need only be performed by those participants sending non-DIS data on the network (i.e., operator interface data). To the best of my knowledge, This includes: BBN, GD, Loral, IDA, IST, NRaD, and Reflectone.

Test Name: PrefixSUT#-12.txt or.bin (ex:IST1-12.txt)

Instructions: To perform the test, the SUT must be connected to its OI target machine as well as to IST. The SUT(s) should then transmit unicast data between themselves. IST will data log the the traffic and verify that the unicast data used the appropriate unicast address.

Results:

Protocol Field	Expected Value	SUT Value
preamble	DC	
start frame delim.	DC	
dest. address	xxx-xxx-xxx-xxx-xxx-xxx	
source address	DC	
type	0x8	
version	4	
IHL	5	
type of service	DC	
total length	DC	
identification	DC	
fragmen. offset	0	
time to live	DC	
protocol	0x11	
header checksum	DC	
source address	DC	
dest. address	132.170.xxx.xxx	
source port	DC	
dest. port	0xBB8 (3000)	
length	DC	
checksum	DC	
data	DC	

RECEPTION TEST

This test is mandatory for Listen Only devices (i.e., stealths, radars, network monitors, etc.) and for simulators/CGF.

Instructions: To perform the Reception test, go the to data logger directory and type "PLAYBACK PTOP.BIN"

Results: Was this test performed? If so, did the SUT ignore the data?

Comments:

2. PDU TESTS

This test should be analyzed on the spot. The SUT may go to the next level of testing regardless of having all fields correct. All of the PDU tests should be data logged together.

Test Name: PrefixSUT#-2.txt or.bin (ex:IST1-2.txt)

2.1 Entity State

<u>TRANSMISSION</u>

This test is mandatory for simulators/CGF.

Instructions: Ask the testers what data the SUT will be sending for Selected by SUT (SBS) values. Record this response in the fields that follow. The SUT should then broadcast an ESPDU onto the network. The data should be recorded with the data logger.

Results:

Protocol Field	Expected Value	Selected Value	SUT Value
header.version	x01		
header.exercise	x01		
header.kind	x01		
header.unused_8	DC		
entityID.simulator.site	SBS		
entityID.simulator.host	SBS		
entityID.entity	SBS (>=1)		
unused 8	DC		
forceID	x1 (blue)		
entityType	SBS		
guise.entityKind	x00		
guise.domain	x00		
guise.country	x00		
guise.category	x00		
guise.sub_category	x00		
guise.specific	x00		
guise.extra	x00		
timeStamp	SBS		

Protocol Field	Expected Value	Selected Value	SUT Value
location.x	SBS		
location.y	SBS		
location.z	SBS		
velocity.x	SBS		
velocity.y	SBS		
velocity.z	SBS		
orientation.psi	SBS		
orientation.theta	SBS		
orientation.phi	SBS		
deadReckonParms.algorithm	x02		
deadReckonParms.unused_8	DC		
deadReckonParms.unused_16	DC		
deadReckonParms.unused_32	DC		
deadReckonParms.unused_32_2	DC		
deadReckonParms.unused_32_3	DC		
deadReckonParms.accel.x	DC		
deadReckonParms.accel.y	DC		
deadReckonParms.accel.z	DC		
deadReckonParms.angularVel.x	DC		
deadReckonParms.angularVel.y	DC		
deadReckonParms.angularVel.z	DC		
appearance	SBS		
marking.characterSet	DC		
marking.text	DC		
capabilities	DC		
unused_16_2	DC		
unused_8_2	DC		

If numparts = 0, there should be no more data in the PDU. If numparts = 2 (expect this for tanks or Bradlys), data should follow. Be sure to check the length of the ESPDU (in the UDP header). If the SUT has no articulated parts, the length should be 144, otherwise the length should be 176 octets.

Protocol Field	**Expected Value**	**Selected Value**	**SUT Value**
numParts	SBS		
parts[0].change	SBS		
parts[0].partID	SBS		
parts[0].numberParms	SBS		
parts[0].partsParms	SBS		
parts[1].change	SBS		
parts[1].partID	SBS		
parts[1].numberParms	SBS		
parts[1].partsParms	SBS		

RECEPTION

This test is mandatory for Listen Only devices (i.e., stealths, radars, network monitors, etc.) and for simulators/CGF.

Instructions: To perform the Reception test, go the to data logger directory and type "PLAYBACK ENTITY.BIN"

Results: Did the SUT receive the data?

Comments:

2.2 Fire

TRANSMISSION

This test is mandatory for simulators/CGF.

Instructions: Ask the testers what data the SUT will be sending for SBS values. Record this response in the fields that follow. The SUT should broadcast a FPDU onto the network. The data should be recorded with the data logger.

Fields to check:

- attackerID.entity must be >= 1
- if there is a target, the targetID.entity must be >= 1; if the entity is shooting at the ground = 0
- the munitionID record must correlate with the munitionID record in the Detonation PDU
- the eventID record must correlate with the eventID record in the Detonation PDU
- the attackerID.sim.site must correlate with the eventID.sim.site
- the attackerID.sim.host must correlate with the eventID.sim.host
- the burst.munition field indicates the type of munition being fired; check to make sure that the munition type is reasonable for the platform
- check for reasonable values in velocity record

Results:

Protocol Field	Expected Value	Selected Value	SUT Value
header.version	x01		
header.exercise	x01		
header.kind	x02		
header.unused_8	DC		
attackerID.simulator.site	SBS		
attackerID.simulator.host	SBS		
attackerID.entity	SBS		
targetID.simulator.site	SBS		
targetID.simulator.host	SBS		
targetID.entity	SBS		
munitionID.simulator.site	SBS		
munitionID.simulator.host	SBS		
munitionID.entity	SBS		
eventID.simulator.site	SBS		
eventID.simulator.host	SBS		
eventID.event	SBS		
timeStamp	SBS		
location.x	SBS		
location.y	SBS		
location.z	SBS		
burst.munition	SBS		
burst.warhead	SBS		
burst.fuze	SBS		
burst.quantity	SBS		
burst.rate	SBS		
velocity.x	SBS		
velocity.y	SBS		
velocity.z	SBS		
range	SBS		

RECEPTION

This test is mandatory for Listen Only devices (i.e., stealths, radars, network monitors, etc.) and for simulators/CGF.

Instructions: To perform the Reception test, go the to data logger directory and type "PLAYBACK FIRE.BIN"

Results: Did the SUT receive the data?

Comments:

2.3 Detonation

TRANSMISSION

This test is mandatory for simulators/CGF.

Instructions: Ask the testers what data the SUT will be sending for SBS values. Record this response in the fields that follow. The SUT should broadcast a DPDU onto the network. The data should be recorded with the data logger.

Fields to check:

- attackerID.entity must be >= 1
- if there is a target, the targetID.entity must be >= 1; if the entity is shooting at the ground = 0
- the munitionID record must correlate with the munitionID record in the Detonation PDU
- the eventID record must correlate with the eventID record in the Detonation PDU
- the attackerID.sim.site must correlate with the eventID.sim.site
- the attackerID.sim.host must correlate with the eventID.sim.host
- the WorldLocation record should indicate where impact occurred in world coordinates (this will be a very large number)
- check for reasonable values in burst.fuze and burst.warhead fields (page 121-122 of standard)
- check for reasonable values in velocity record
- check the result field for the following:
  + detonation = 0
  + impact on vehicle = 1
    entityLocation record should be ˜10s m for tanks/air, ˜100s m sea
  + sky shot = 2

Results:

Protocol Field	Expected Value	Selected Value	SUT Value
header.version	x01		
header.exercise	x01		
header.kind	x03		
header.unused_8	DC		
attackerID.simulator.site	SBS		
attackerID.simulator.host	SBS		
attackerID.entity	SBS		
targetID.simulator.site	SBS		
targetID.simulator.host	SBS		
targetID.entity	SBS		
munitionID.simulator.site	SBS		
munitionID.simulator.host	SBS		
munitionID.entity	SBS		
eventID.simulator.site	SBS		
eventID.simulator.host	SBS		
eventID.event	SBS		
timeStamp	SBS		
worldLocation.x	SBS		
worldLocation.y	SBS		
worldLocation.z	SBS		
burst.munition	SBS		
burst.warhead	SBS		
burst.fuze	SBS		
burst.quantity	SBS		
burst.rate	SBS		
velocity.x	SBS		
velocity.y	SBS		
velocity.z	SBS		

Protocol Field	Expected Value	Selected Value	SUT Value
entityLocation.x	SBS		
entityLocation.y	SBS		
entityLocation.z	SBS		
result	SBS		
numParts	0		

RECEPTION

This test is mandatory for Listen Only devices (i.e., stealths, radars, network monitors, etc.) and for simulators/CGF.

Instructions: To perform the Reception test, go the to data logger directory and type "PLAYBACK DET.BIN"

Results: Did the SUT receive the data?

Comments:

2.4 Collision

TRANSMISSION

This test is mandatory for simulators/CGF generating sea and land entities only (not required for air vehicles).

Instructions: Ask the testers what data the SUT will be sending for SBS values. Record this response in the fields that follow. The SUT should broadcast a CPDU onto the network. The data should be recorded with the data logger.

Fields to check:

- check to make sure that the issueID record correlates with the entityID of the vehicle sending the PDU

- check to make sure that the velocities and positions are reasonable

Results:

Protocol Field	Expected Value	Selected Value	SUT Value
header.version	x01		
header.exercise	x01		
header.kind	x04		
header.unused_8	DC		
issueID.simulator.site	SBS		
issueID.simulator.host	SBS		
issueID.entity	SBS		
collideID.simulator.site	SBS		
collideID.simulator.host	SBS		
collideID.entity	SBS		
eventID.simulator.site	SBS		
eventID.simulator.host	SBS		
eventID.event	SBS		
unused_16	DC		
timeStamp	SBS		
velocity.x	SBS		
velocity.y	SBS		
velocity.z	SBS		
mass	SBS		
location.x	SBS		
location.y	SBS		
location.z	SBS		

RECEPTION

This test is mandatory for Listen Only devices (i.e., stealths, radars, network monitors, etc.) and for simulators/CGF.

Instructions: To perform the Reception test, go the to data logger directory. Type: "PLAYBACK COLL.BIN"

Results: Did the SUT receive the data?

Comments:

3. TERRAIN ORIENTATION TESTS

This test will be evaluated in two ways: mathematically and visually. The calculations will be done off-line, the visual verification is dependent on the availability of a stealth. (Warning: Visual verification is totally dependent on the terrain databases and support point used.)

3.1 Orientation Transmission Tests

TRANSMISSION

This test is mandatory for all simulators/CGF.

Test Name: PrefixSUT#-31.txt or.bin (ex:IST1-31.txt)

Instructions: The SUT should follow the course stated in the Test Plan for the appropriate vehicle. Data log the Entity State PDUs generated by the SUT. Record the following data from three adjacent PDUs.

SAMPLE 1:

Position (x,y,z) =

Velocity (vx,vy,vz) =

Time =

SAMPLE 2:

Position (x,y,z) =

Velocity (vx,vy,vz) =

Time =

SAMPLE 3:

Position (x,y,z) =

Velocity (vx,vy,vz) =

Time =

Results: To analyze the data, go to directory TEST and type "deadrec". The program will prompt you to enter the position, velocity, and time information. We are testing the position correlation based on the internal values of position velocity, and time. Are samples internally consistent (i.e., X2 = X1 + (T2-T1)* V1)? If not, why?

Was a visual verification made? If so, the movement of the vehicle should be smooth.

Comments:

RECEPTION

This test is by request only for Listen Only devices (i.e., stealths, radars, network monitors, etc.) and for simulators/CGF.

Instructions: To perform the Reception test, IST should replicate entity type and course generated by the SUT in the TRANSMISSION test.

Results: Was this test performed? If so, did the SUT receive the data?

Comments:

4. APPEARANCE TESTS

These tests will be evaluated in two ways: mathematically and visually. The Location tests will require off-line calculations. The Attitude test can be verified with a plan view display; however, a stealth is more desirable.

4.1 Location and Attitude

4.1.1 Location Tests

TRANSMISSION

This test is mandatory for all simulators/CGF.

Test Name: PrefixSUT#-411.txt or.bin (ex:IST1-411.txt)

Instructions: The SUT should go to the position stated in the Test Plan. Data log the Entity State PDUs generated by the SUT. The SUT should generate Entity State PDUs for approximately one minute. Record the following data from three adjacent PDUs.

Sample 1:

Position (x,y,z) =

Time =

Sample 6:

Position (x,y,z) =

Time =

Sample 11:

Position (x,y,z) =

Time =

Results: The actual position should be within 1 meter of stated position. This can be determined by observation. Did the SUT meet the tolerance?

The ESPDUs should have been sent at approximately .2 Hz (at least every 5 seconds)? This can be calculated using the "deadrec" program in the TEST directory. At what rate did the SUT generate ESPDUs?

Comments:

RECEPTION

This test is by request only for Listen Only devices (i.e., stealths, radars, network monitors, etc.) and for simulators/CGF.

Instructions: To perform the Reception test, IST should replicate entity type and position generated by the SUT in the TRANSMISSION test.

Results: Was this test performed? If so, did the SUT receive the data?

Comments:

4.1.2 Attitude Tests

TRANSMISSION

This test is mandatory for all simulators/CGF.

Test Name: PrefixSUT#-412.txt or.bin (ex:IST1-412.txt)

Instructions: The SUT should follow the course stated in the Test Plan. Data log the Entity State PDUs generated by the SUT.

Results: If a plan view display is used to verify the test, only yaw can be observed. The tester should observe the following: when the SUT turned through 360 degrees, the turn should have been smooth and the entity should have continued to travel in the correct direction.

Comments:

RECEPTION

This test is by request only for Listen Only devices (i.e., stealths, radars, network monitors, etc.) and for simulators/CGF.

Instructions: To perform the Reception test, IST should replicate entity type and course followed by the SUT in the TRANSMISSION test.

Results: Was this test performed? If so, did the SUT receive the data?

Comments: