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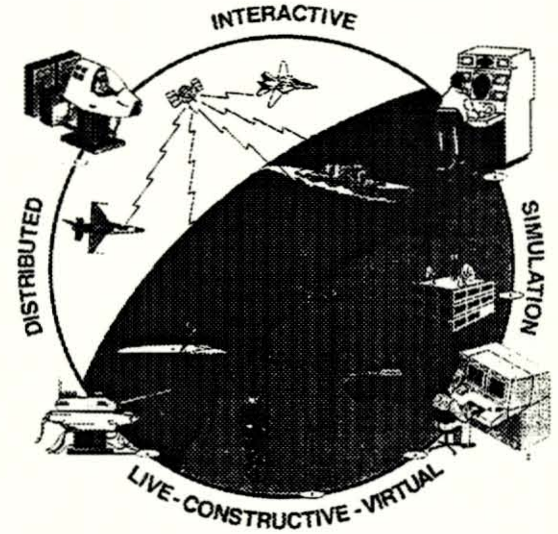
The DIS Vision: A Map To The Future Of Distributed Simulation

University of Central Florida Institute for Simulation and Training

The DIS Vision

A Map to the Future of Distributed Simulation



Prepared by:
DIS Steering Committee

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Preface

This document represents the current status of the DIS standards development and outlines plans for future development. Early versions of this document were created, reviewed, and modified by the DIS Steering Committee. The version previous to this one (marked October 93 Comment Draft) was distributed for feedback and comment to the whole DIS community and the modeling and simulation community at large. This final draft is based on the feedback from the community on that draft. The document will be updated on a biennial basis.

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Acronyms

A2ATD	Armor/Anti-Armor Advanced Technical Demonstration
AAW	Anti-Air Warfare
ACC	Air Combat Command
ADS	Advanced Distributed Simulation
ADST	Advanced Distributed Simulation Technology
ALSP	Aggregate Level Simulation Protocol
AMW	Amphibious Warfare
ARPA	Advanced Research Projects Agency
ASUW	Anti-Surface Warfare
ASW	Anti-Submarine Warfare
ATD	Advanced Technology Demonstration
AUSA	Association of the US Army
AVTB	Aviation Test Bed
AWSIM	Air Warfare Simulation
BFTT	Battle Force Tactical Trainer
BG	Brigadier General
BMDO	Ballistic Missile Defense Organization
C4I	Command, Control, Communications, Computers, and Intelligence
CAC2	Combined Arms Command and Control
CADIS	Communications Architecture for Distributed Interactive Simulation
CATT	Combined Arms Tactical Trainer
CBS	Corps Battle Simulation
CCTT	Close Combat Tactical Trainer
CGF	Computer Generated Forces
CPX	Command Post Exercise
CSRDF	Crew Station Research and Development facility
CV	Aircraft Carrier
DARPA	Defense Advanced Research Projects Agency (former name for ARPA)
DIS	Distributed Interactive Simulation
DISA	Defense Information Systems Agency
DMSO	Defense Modeling and Simulation Office
DOT	Department of Transportation
DSB	Defense Science Board
DSI	Defense Simulation Internet
DoD	Department of Defense
E3	End-to-End Encryption
EC	Electronic Combat
ECM	Electronic Countermeasures
ECCM	Electronic Counter-countermeasures
ENWGS	Enhanced Naval Wargaming System
EW	Electronic Warfare
FAA	Federal Aviation Administration
GOSIP	Government Open Systems Interconnection Profile
HITL	Human-in-the-Loop

HY-DY	High Dynamics Vehicles Project
I/ITSEC	Interservice/Industry Training Systems and Education Conference
ID	Identification
IEEE	Institute of Electrical and Electronic Engineers
IR&D	Internal Research and Development
ISO	International Standards Organization
IST	University of Central Florida Institute for Simulation and Training
ITMC	Interface/Time Mission Critical
JCS	Joint Chiefs of Staff
JMASS	Joint Modeling and Simulation System
JTF	Joint Task Force
JWFC	Joint Warfighting Center
LAM	Louisiana Maneuvers
LAN	Local Area Network
MAIS	Mobile Automated Instrumentation Suite
MDEP	Modernization Development Plan
MIW	Mine Warfare
MCCDC	Marine Corps Combat Development Command
MTWS	Marine Air Ground Task Force Tactical Warfare Simulation
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NATO	North Atlantic Treaty Organization
NAVAIR	Naval Air Systems Command
NAVSEA	Naval Sea Systems Command
NSA	National Security Agency
NSC	National Simulation Capability
NTC	National Training Center
NTF	National Test Facility
OSD	Office of the Secretary of Defense
OSI	Open Systems Interconnection
PDU	Protocol Data Unit
RF	Radio Frequency
SC	Steering Committee
SEW	Space and Electronic Warfare
SIG	Special Interest Group
SIMNET	SIMulator NETworking
SOF ATS	Special Operations Forces Aircrew Training Systems
STANAG	Standardization Agreement
STOW	Synthetic Theater of War
STRICOM	US Army Simulation, Training, and Instrumentation Command
STW	Strike Warfare
T & E	Test and Evaluation
TACCSF	Theater Air Command and Control Simulation Facility
TBD	To Be Determined
TCP/IP	Transmission Control Protocol / Internet Protocol
TCTS	Tactical Combat Training System
TRADOC	Army Training and Doctrine Command
USSOCOM	US Special Operations Command

UTSS	Universal Threat System for Simulators
VR	Virtual Reality
VV&A	Verification, Validation, and Accreditation
WAN	Wide Area Network
WARSIM	Warfighter Simulation

Introduction

One of the emerging capabilities of real-time simulation is the ability to create large virtual worlds in which many subjects can interact. This is being done by electronically linking individual simulations. The creation of such virtual worlds makes possible:

- Training of large scale forces in a realistic environment not before attainable
- Planning and rehearsal of operational missions
- Development of new tactics and concepts of operation
- Testing of the efficacy of new systems very early in their development cycles

Visionaries are taking advantage of these developments to revolutionize planning, training, testing, and acquisition. The movement to create these large virtual worlds is called Advanced Distributed Simulation (ADS). Almost every major simulation being procured today will become part of ADS. Leaders of this effort are the Advanced Projects Research Agency (ARPA), Joint Warfighting Center (JWFC), Defense Modeling and Simulation Office (DMSO), the Simulation Training and Instrumentation Command (STRICOM) of the Army, and the Federal Aviation Administration (FAA).

However, to make such ADS capabilities a reality, a standards infrastructure has to be established to make the individual simulations interoperable. Standards are needed in the areas of interfacing, communications, representation of the virtual environment, management, security, and performance measurement.

In 1989 a small group of farsighted individuals within the defense community organized a series of workshops, the goal of which is to create the standards to support the ADS movement. This support movement has come to be known as Distributed Interactive Simulation (DIS). DIS workshops have met on a semi-annual basis since the initial meeting. The movement has been playing an increasingly important role. Over 1100 individuals attended the most recent workshop (March 94). Most recent major Department of Defense (DoD) simulation acquisitions have required adherence to DIS standards. The FAA intends to adopt DIS standards for the National Simulation Capability program. The entertainment industry has expressed interest in adopting the standards for emerging simulation applications in theme parks and distributed games.

This document was written to provide a focus for future development of DIS standards and supporting technology. It includes:

- A vision of the major capabilities of DIS-based applications
- An assessment of the current status of the DIS movement including its strengths, challenges that it faces, opportunities that lie before it, and critical issues that the movement must deal with if it is to be successful.
- A map to its future in the form of a set of general goals and associated objectives that can be reached in the next two years or five years or which must wait for developments that are not anticipated within the next five years.

SECTION 1

THE VISION

The primary mission of DIS is to define an infrastructure for linking simulations of various types at multiple locations to create realistic, complex, virtual "worlds" for the simulation of highly interactive activities. This infrastructure brings together systems built for separate purposes, technologies from different eras, products from various vendors, and platforms from various services and permits them to interoperate. DIS exercises are intended to support a mixture of virtual entities (human-in-the-loop simulators), live entities (operational platforms and test and evaluation systems), and constructive entities (wargames and other automated simulations).

The DIS infrastructure provides interface standards, communications architectures, management structures, fidelity indices, technical forums, and other elements necessary to transform heterogeneous simulations into unified seamless synthetic environments. These synthetic environments support design and prototyping, education and training, test and evaluation, emergency preparedness and contingency response, and readiness and warfighting.

... DIS Mission

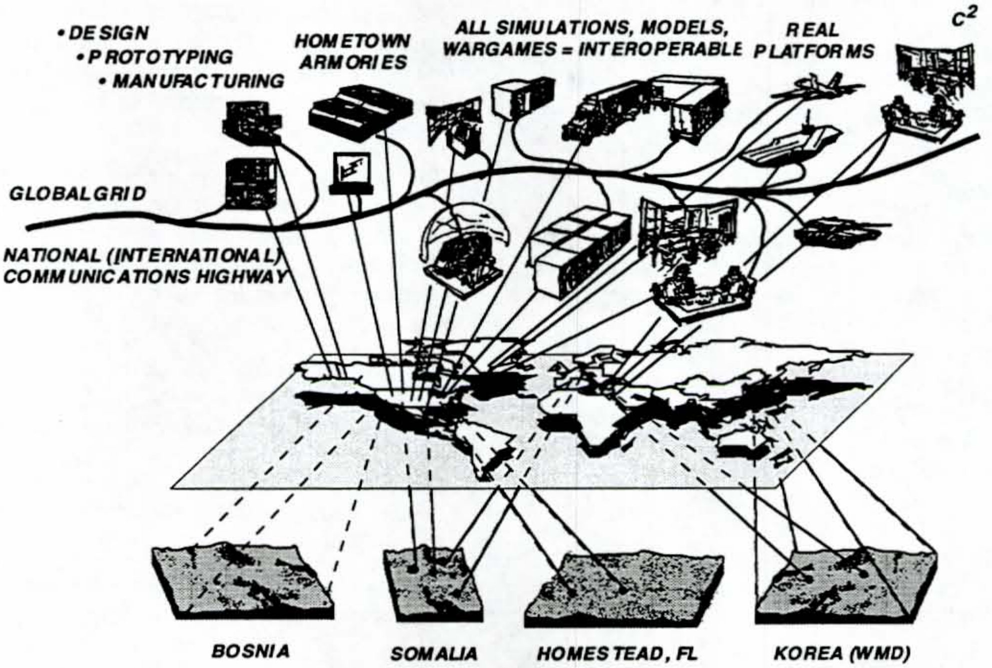

Figure 1-1. Distributed Interactive Simulation permits a wide variety of simulators, wargames, and live ranges to interoperate in joint operations for training, mission rehearsal, and material development and evaluation.

1.1 The Concept

In DIS, the world is modeled as a set of "entities" that interact with each other by means of "events" that they cause. These events may be perceived by other entities and may have effects on them, which in turn may cause other events that affect other entities.

At the heart of DIS, is a set of protocols that convey messages about entities and events, via a network, among various simulation nodes that are responsible for maintaining the status of the entities in the virtual world. The characteristics of the network are not important, as long as it can convey these messages to the interested simulation nodes with reasonably low latency (100 to 300 milliseconds) and low latency variance. Within these constraints, the systems that generate entities that appear to be adjacent in the virtual world could be separated by thousands of miles in the real world.

DIS is being envisioned as not only a tool to establish a synthetic battlefield of distributed simulations, but is also being examined in a wide spectrum of applications. Military missions including test and evaluation, mission rehearsal and training, and research and development are planning to utilize DIS. Other applications include civil aviation command and control, disaster relief, distributed simulation games and coordinated team training efforts. All these missions bring specific challenges to the development of interoperability standards.

1.1.1 Categories of Simulations

The historical core of DIS has been continuous, real-time, human-in-the-loop simulations, which have been designated as "virtual" simulations to contrast them with "live" and "constructive" simulations. Virtual simulations include the original DARPA SIMNET (Simulator Networking) project in which the antecedents of the DIS protocols were developed, as well as the Army's current Advanced Distributed Simulation Technology (ADST) and Close Combat Tactical Trainer (CCTT) programs. The Navy's Battle Force Tactical Trainer (BFTT), the Air Force's Theater Air Command and Control Simulation Facility (TACCSF), and the FAA's National Simulation Capability (NSC) also qualify as virtual simulations.

DIS is also intended to interface with "live" simulations: those involving crews in real vehicles, moving on instrumented ranges. Examples include the Army's National Training Center, the Navy's "Strike University," the Air Force's Red Flag ranges, and the Marine Air Ground Combat Center.

DIS will also interface (within certain constraints) with more automated wargames, called "constructive" simulations, such as the Army's Corps Battle Simulation (CBS), the Navy's Enhanced Naval Wargaming System (ENWGS), the Air Force's Air Warfare Simulation (AWSIM), and the Marine Air Ground Task Force Tactical Warfare Simulation (MTWS).

These various categories of simulations may all interoperate in a single exercise, or multiple exercises, simultaneously on a single network. Figure 1-1 is a conceptual representation of what a large exercise might involve.

1.1.2 DIS Capabilities

The initial focus of DIS-based application has been on training, especially the training of large, joint, or combined forces. As noted in the accompanying quotation from a recent Defense Science Board Report, this is an area in which it is particularly difficult (and expensive) to train effectively, and hence something that our military services do not do very often or very well.

The Services train individual soldiers, sailors, airmen, and marines and provide highly trained combat units and do a very good job. [... But] some things we don't do well. First and foremost among these is the training and exercising of large, joint, or combined forces to fight on short notice.[1]

Closely associated with training is mission rehearsal, in which essential coordination procedures are worked out and the holes in the Command, Control, and Communication structure are found and filled. As noted in another excerpt from the same report, this is another area of substantial need.

Achieving joint interoperability remains a challenging problem. There are currently over 300 C4I systems, many of which do not interoperate. There are also doctrine and concept disconnects. During the Gulf War, ad hocery was employed to solve many of these problems. The solutions have now been dismantled.[2]

Further extensions of training and mission rehearsal led to the development and evaluation of tactical doctrine, and to the detailed reconstruction of actual battles for further analysis, as was done recently for the Battle of 73 EASTING in the Gulf War.

Beyond these areas, there is the definition of requirements for new battlefield systems, so that one can feel reasonably sure of the effectiveness of proposed systems

before embarking on a lengthy and expensive development process. Concurrently with engineering development, one can begin the development and revision of tactical doctrine associated with the capabilities of the new system. One can perform tradeoff studies to learn the probable effects of including various features. One can do initial prototype evaluation and rehearse field tests to save valuable test range time.

We believe that Advanced Distributed Simulation (ADS) technology is here today, and that this technology can provide the means to:

- *improve training and readiness substantially*
- *create an environment for operational and technical innovation for revolutionary improvements*
- *transform the acquisition process from within[3]*

1.2 DIS Areas of Standardization

As identified in the mission statement, the primary function of the DIS community is to define and provide the infrastructure necessary to combine individual simulations into a seamless virtual world. A key part of this infrastructure is a series of standards in the areas of interface definition, communication, representation of the environment, management, security, field instrumentation, and performance measurement. Each of these areas is discussed further in the following subsections. Specific goals and objectives associated with each of these areas are defined in the last section of this document.

1.2.1 Interface Definition

Most of the DIS standards work thus far has centered on the definition of information that must flow between simulations to make them interoperable. These definitions include:

- Identification of data items
- A common representation of these data items
- The assembly of these data items into formatted messages, called Protocol Data Units (PDUs)
- The circumstances (including time) under which these PDUs are transmitted
- The processing that must be done on receipt of PDUs
- Key algorithms (e.g. dead reckoning) that must be implemented by all participants

These definitions have been assembled into a document called the "Standard for Information Technology - Protocols for Distributed Interactive Simulation Applications." The initial version of the document (DIS 1.0) was approved on 17 March 1993 as Institute of Electrical and Electronic Engineers (IEEE) Standard 1278. This version defines the PDUs needed to support the appearance and movement of entities, firing of weapons, detonation of ordnance, collision detection, and logistical resupply of units.

Subsequent versions of this document are available as working drafts (DIS 2.X series) to support current demonstrations and developments. These drafts represent a major upgrade to the initial version to correct shortcomings and to support the following new capabilities:

- Simulated voice radio and tactical data links
- Simulation management
- Emission representation in support of electronic warfare
- Future versions of this document will address:
- Terrain description
- Environmental effects

  Sensor effects modeling

  Communication of persistent effects to simulators not present at the time of an event (e.g., shell craters, blown bridges)

1.2.2 Communications Architecture

DIS PDUs are independent of network media and network protocols being used to transmit them. That is, the PDUs define the information that flows between simulations; and communications architecture standards ensure that the underlying media, types of service, and protocols are common and meet key performance requirements. Communications standards work is centered on the following areas:

- Definition of addressing (e.g. point-to-point, one-to-many) capabilities
- Definition of reliability (e.g. error free, best effort) requirements
- Choice of communication profile for the network and transport layers (as defined by the International Standards Organization/Open System Interconnection (ISO/OSI) technical reference model).
- Guidance in determining bandwidth requirements based on estimated traffic for exercises of different sizes

- Definition of key constraints (e.g. maximum PDU size)
- Definition of key performance capabilities (e.g. latency)

A draft standard called "Communications Architecture for Distributed Interactive Simulation (CADIS)" has been approved by the DIS steering committee. It is being transferred to the IEEE for balloting and final approval.

Unlike the definition of PDUs, which can be arbitrarily defined to suit specific DIS needs, communications standards are heavily impacted by what the communications industry offers or is expected to offer. Many fundamental communications needs of DIS (e.g. multicast addressing) are the antithesis of traditional communications developments, which are based on the telephone model of point-to-point connection. This has made the selection of available services difficult and has forced some compromises in DIS operations. To some extent the DIS community can also influence the direction of certain industry developments by making its requirements clear and making them known to developers in the communications industry.

1.2.3 Security

Many if not most DIS-based applications will require protection of the information flowing between simulations. The applications which require protection will range from individual companies wishing to keep proprietary data away from competitors to rehearsal of planned military operations, the most sensitive application foreseen. DIS standards development in the area of security consists of:

- Establishment of a DIS security policy
- Publication of a DIS security guidance document
- Publication of security accreditation guidelines
- Establishment of security service performance requirements

It should be noted here that none of the efforts mentioned above will in any way determine what data needs protection or how well the data needs to be protected. These issues are the responsibility of the authority in charge of each DIS simulation application and will vary from application to application. Instead, these efforts are intended to assist accreditors, engineers, and managers in determining what protection measures are available and how they may be most effectively used. These efforts will also clarify the needs of DIS data protection mechanisms to help the developers of such mechanisms (e.g. encryption/decryption devices, secure operating systems, key distribution methods). Another purpose is a standardized accreditation process for DIS-based applications that is widely understood and easily used.

1.2.4 Management

The planning, setup, execution, and monitoring of a large, multi-site exercise is a complex process that may ultimately prove to be a greater challenge than managing the network traffic itself. Significant amounts of person-to-person communication, via video conferencing and other techniques, will be required in advance of an exercise to insure that the exercise objectives are understood and agreed to by all parties involved, and that the required resources, in terms of simulations, personnel, and communications bandwidth, are available at the appropriate times.

Another daunting dimension of this problem is configuration management, particularly where many heterogeneous simulations are involved. Each simulation has its own set of adjustable parameters, each of which must be recorded if there is to be any chance of replicating the exercise. Where interfaces to wargames are included, they can easily represent thousands of parameters to be recorded.

The effort to develop DIS management standards is separately focusing on the areas of exercise management, network management, and security management, each of which is described below.

1.2.4.1. Exercise

The contribution to be made by the DIS standards development effort to exercise management consists of:

- PDUs to control the exercise (start, stop, reset, replay, add/remove entities, terminate, etc.).
- Policies and guidance to assist users and exercise designers in creating exercises in which all elements are compatible with one another, valid individually and as a group for the exercise purpose, and contribute to the "fair fight".
- A clear, widely promulgated, and well understood set of procedures for the planning, initialization, conduct, and analysis of exercises.

1.2.4.2. Network

Much of the work involved in creating and conducting a DIS exercise is the management of the network connecting the simulation hosts and sites. This work can be facilitated by tools which can:

- Allocate and promulgate addresses (including multicast) to be used by the simulation hosts and sites.
- Establish the connections between all elements of an exercise.
- Monitor and control the network and reconfigure it if failures or changing circumstances require.

It is the role of the DIS standards development effort to encourage and guide the development of these tools to the extent possible and provide guidance for their use.

1.2.4.3. Security Management

Although the DIS community is concerned with general security issues (e.g. policy, accreditation processes), the management of security during an exercise requires special attention. The security requirements of DIS exercises will vary greatly. Variation of requirements may well exist in the same exercise. To help manage these security problems, the DIS standards community must establish a standard process to:

- Define security requirements
- Establish the protection needed to meet those requirements
- Get the necessary accreditation of those protective measures

1.2.5 Environment

The synthetic environment needs to present a full-bodied, integrated representation of land, air, and sea (figure 1-2). Two considerations affect this issue: fidelity of environmental representation (for validation of the simulation exercise consistent with the exercise purpose), and correlation of representations from system-to-system to ensure the fair fight. The concept of a fair fight also includes:

- Adequate inclusion of entity capability to support individual actions (e.g. controls and displays, subsystems, modes of operation, physical limitations).
- Accurate representation of actions by all affected participants

DIS efforts for achieving this harmony of environmental representation among heterogeneous simulators, simulations, and range systems are focused on an infrastructure to:

- Identify common sources for environmental data,
- Create standards for the representation of that data,
- Create repository databases for the collection and storage of the common data,
- Distribute that data to local systems in an exercise.
- Aid DIS users in identifying exercise requirements and then decomposing them into participant capabilities and fidelity requirements.
- Catalog DIS qualified simulation assets from which

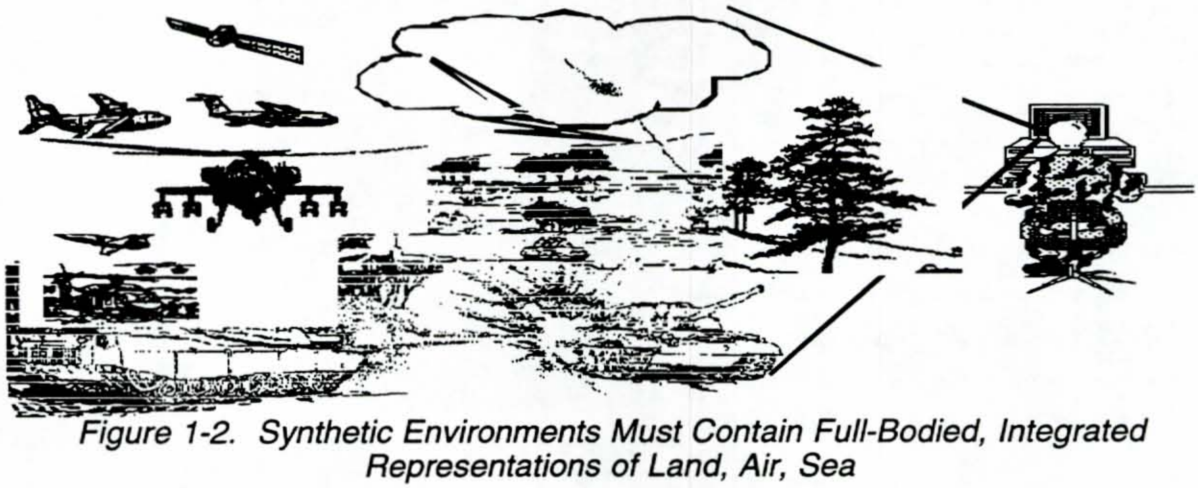

Figure 1-2. Synthetic Environments Must Contain Full-Bodied, Integrated Representations of Land, Air, Sea

DIS users can select an appropriate subset to meet exercise goals, including exercise validation.

1.2.6 Field Instrumentation

Instrumented platforms have unique requirements that are not addressed by historic mainstream DIS standards. To address these issues the DIS community has established a separate effort to develop standards that will allow instrumented platforms to interact with virtual and constructive simulation components in a meaningful way. Some of the areas addressed by this effort include:

- More compact representation of data necessitated by the lower bandwidth of RF communications used by the instrumented ranges
- The special needs of mobile instrumented platforms
- The fusion of simulated information with that provided by the sensors of the instrumented platforms
- Intelligent translation of information flowing from the instrumented range to the virtual world
- The special safety considerations of live range interactions.
- Interfaces which allow exchange of tactical data link information between live, virtual and constructive simulations.
- Special protocols to handle live range activities.

1.2.7 Performance Measurement

In order for a DIS-based application to have value that can be stated objectively, a great deal of effort must be put into defining, recording, and analyzing data that represents the behavior of the participants. Such measures of performance are essential to the Verification, Validation, and Accreditation (VV&A) needed to determine whether a planned DIS-based application is appropriate to its intended purpose. Eventually such performance measurement will also be the basis of efforts to determine the effectiveness of behaviors seen in DIS-based applications.

Standards development efforts in the area of performance measurement center on:

- Establishing a standard set of performance measures
- Developing mechanisms to gather appropriate data
- Identifying and extracting meaningful parameters from that data
- Presenting such parameters in a manner that is easy to understand and absorb
- Collecting data from remote sites at a central location

A standard set of fidelity characteristics and descriptors is being developed by the Fidelity Description Requirements Subgroup. The resulting taxonomy of fidelity descriptors will become an integral part of the DIS VV&A process.

1.2.8 Computer Generated Forces

Most DIS exercises have been and will be much larger than can be practically populated with human-in-the-loop (HITL) simulators. Therefore, it is necessary to have many entities in the exercise that operate under the loose supervisory control of human operators. Such computer generated forces (CGF) include not only the platform level entities which emit standard entity state PDUs, but also the command and control hierarchy representing the missing human commanders. Development of a CGF standard aims to achieve the same degree of uniformity and openness in CGF interactions as in physical interactions, without unnecessarily restricting the knowledge representation or decision processes underlying those interactions.

Computer generated forces have different requirements and capabilities from HITL simulators, flowing largely from the differences in cognitive and perceptual abilities of CGF compared to human operators or commanders. For current or near-term systems, we realistically assume CGF entities, at the "platform" level, with limited perceptual and cognitive abilities.

Interoperability of such entities (among themselves or with human elements of a DIS configuration) will demand DIS standards that accommodate such CGF limitations as:

Relatively primitive natural language processing capability.

Restricted capability to interpret and use visual/graphic data such as maps, out-the-window visual scenes, etc.

Relative lack of explicit representations for the large body of tacit common sense knowledge that human operators assume each other to have.

DIS standards development in the area of CGF consists of:

- Representation of the air, land, and sea environments in such a way as to minimize the computational burden on CGFs in areas such as intervisibility, route planning, obstacle detection, and so on.
- Representation of command and control, in such a way as to promote the smooth cooperation of heterogeneous CGF during an exercise. Data to be represented include mission orders, reports of events or current tactical state, and task organization.
- Setup data and procedures so that heterogeneous CGF can be rapidly and reliably initialized in a known state before participating in a DIS exercise.

1.3 Future Considerations.

Presently, the mission of DIS is expanding. DIS standards will be modified to meet new roles and will be refined to increase efficiency. Some of these expansions and refinements are described below:

Entertainment and Education Fields. DIS is now being considered as a tool to provide distributed entertainment and education programs. Application of DIS in this area will almost certainly require modification to the existing standards, which are now primarily addressing military applications.

Greater Emphasis on Non-Ground Based Platforms, Emissions and C4I. The DIS working groups and special interest groups (SIGs) such as the Dead Reckoning SIG are addressing additional changes to the standards to produce a more robust environment for the inclusion of high speed aircraft and weapons, and electromagnetic and acoustic emissions. Electromagnetic emissions include radars, radio and tactical data links.

Greater Emphasis on Mobile Simulation Sites. The addition of live entities into the synthetic environment has produced a requirement to communicate with entities on the move. The Field Instrumentation Working Group is beginning to address the special needs of the live environment and its interface to the virtual environment. Limited RF bandwidth and communication latencies are being considered.

Support Increasingly Large Numbers of Entities. The initial DIS demonstration at the I/ITSEC in San Antonio in November 1992 was a proof of concept demonstration involving about 200 virtual entities. Near term goals for entities in the synthetic environment are around 10,000. Future goals established by ARPA involve about 100,000 entities in a DIS exercise. Research by various agencies is ongoing to tackle the communication architecture and protocol schemes to enable large numbers of entities to interact in real-time in a DIS exercise. Critical technologies include the development of computer generated forces (CGFs), improved dead reckoning algorithms, filtering mechanisms, and other schemes to reduce bandwidth requirements.

Support 'Quick Look' Exercises. The eventual goal of having many simulation assets available for configuration into a given DIS exercise provides unique opportunity to support 'quick look' analysis tasks. DIS components can be quickly assembled to replicate a variety of environments. This will yield better quality data at a lower cost, providing the asset selection and environment validation issues can be worked out.

Increase Emphasis on VV&A. Recognition of the importance of verification, validation, and accreditation of models and simulations, including distributed simulations, is increasing with the Defense community. The military Services and Defense agencies are establishing formal VV&A policies, procedures, and guidelines; and a VV&A instruction for the entire Defense community is being prepared. This subject area is very much of concern within the FAA's NSC program VV&A processes for DIS and any VV&A-related portions of evolving standards must be compatible with these VV&A endeavors within the military Services, Defense agencies, and the FAA. Close cooperation between leadership of the DIS VV&A Sub-group and the leadership of these Defense VV&A activities is essential. Identification of automated tools and techniques to assist in this VV&A process must be a major goal of the workshops.

Examine Possible Limitations to the DIS Process. Expectations of what can be done in the virtual worlds created by DIS are growing. At some point it may be necessary to look at inherent limits of the process to curb unrealistic expectations and subsequent disillusionment.

SECTION 2

OVERVIEW

2.1 Objectives

This document has the following objectives:

Provide Better Focus for Development of DIS. DIS is being developed through an industry consensus standard approach. This approach has the distinct advantage that it allows all interested members of industry, government, and academia to propose their recommended approaches for achieving the DIS goals and subjecting these recommendations to the scrutiny of the other participants. The approaches that best serve the needs of DIS tend to be supported by other members of the DIS community and are incorporated into the standards.

The disadvantage of this approach is that the efforts can sometimes become unfocused if everyone does not share the vision of where DIS is headed. This document was produced to provide to the DIS community a vision of where DIS is headed and when we believe it will achieve various intermediate goals. It is hoped that this document will orient the DIS community and focus the efforts of the participants to achieve the DIS goals with the least amount of effort.

Help Government Decide When Capabilities Will Be Ready. At this time, the government is the primary customer for DIS. The government has identified a number of needs that can be fulfilled more cost-effectively using DIS than by alternative means. The government needs a vision of where DIS is headed in order to plan and budget for the use of the various DIS functional capabilities as the technology becomes mature and usable. This document will, hopefully, help the government plan for the future implementation of DIS capabilities.

Help Industry Plan IR&D. One of the primary tenets of DIS is that if industry consensus standards (defining an open architecture) are developed, then industry will develop reusable hardware/software that they can sell to a number of customers at a lower price than would be the case in one-of-a-kind procurements. Companies develop these reusable products using internal research and development (IR&D) funds. Naturally, industry managers are reluctant to spend their money on product development unless they have a clear understanding of what product performance characteristics will be required by the customer and when. This document was produced to give industry an idea when various functional components of DIS will be defined, what performance capabilities are likely to be required by potential customers in the future, and when to those requirements are expected.

Provide DIS "Ownership." Another reason for presenting the vision of where DIS is going, is to allow a larger portion of Government, Industry and Academia to get more involved in its development. This increased involvement is almost certain to develop a feeling of ownership similar to that felt by the DIS participants who have been more intimately involved in DIS up to this point.

Better Education of Potential Users. A number of organizations are considering the use of DIS but do not have a sufficient understanding to decide whether it will improve their operations. Others have decided that DIS will allow them to achieve their objectives in a cost-effective manner but require a better understanding of DIS to use it effectively. This document, along with others, will assist the potential user in deciding how best to use DIS.

Minimize False Expectations. In addition to helping potential users understand DIS, it is critical that these users not develop false expectations that DIS is some magic tool that can solve any problem. This document will help the potential user achieve a better understanding of the capabilities and limitations of DIS, thereby minimizing false expectations.

Assist Funding Organizations. DIS depends heavily on emerging technologies. Funding to develop these technologies is required to bring DIS up to its full potential. By laying out the capabilities and limitations of DIS and explaining what capabilities must be developed when, this document will assist funding organizations to determine what funding will be required in various technologies during the next two years, five years, or beyond.

2.2 Scope

This document is a long range plan to provide the focus for continued development of DIS standards and the technology needed to support DIS-based applications. As such it defines the areas of standardization, sets general goals in each of those areas, and identifies measurable objectives that can be used to determine if and when the goals have been met. As part of the planning process, the document also examines the present state of the standards development effort. In particular, it identifies those strengths of the DIS movement that have thus far accounted for its success, examines challenges that can hinder continued success, and identifies opportunities for DIS-based applications.

This document does not advocate the application of DIS standards to any particular program or project, nor does it delve into the political processes, funding issues, benefits, and drawbacks associated with any application.

2.3 Who We Are Planning For

As stated above, this document is meant to assist industry, government and academia in planning for the future implementations of DIS capabilities. But special emphasis is placed on the information needs of sponsors, supporting agencies, users and major programs. These organizations are discussed in Tables 2-1 to 2-3.

A number of government programs are committed to using the DIS standard. The manner in which each of the programs makes use of the standard varies. Some programs will make use of the complete DIS standard set, others will make use of the DIS communications protocol for both internal and external communications, and yet others will only provide a DIS communications interface to the outside world. Table 2-4 lists those

Table 2-1. DIS Sponsors

ORGANIZATION	ROLES
OSD Defense Modeling and Simulation Office (DMSO)	Primary proponent for modeling and simulation in DoD. Provides funding for tri-service efforts such as DIS standards
US Army Simulation, Training and Instrumentation Command (STRICOM)	Primary procuring agency for army training and instrumentation systems. Lead laboratory for development of DIS. Procuring agency for several DIS-compliant systems.
Advanced Research Projects Agency (ARPA)	Developer of SIMNET and many of the basic DIS technologies. Funding agency for several DIS Advanced Technology Demonstrations (ATD)
US Special Operations Command (USSOCOM)	Sponsor for the Special Operations Forces Aircrew Training Systems (SOF ATS)
Naval Air Systems Command (NAVAIR)	Sponsor for the Tactical Combat Training System (TCTS)
Naval Sea Systems Command (NAVSEA)	Sponsor for BFTT
Air Force Air Combat Command (ACC)	Sponsor for TACCSF
Air Force Space Command (AFSPACECOM) and Air Force Ballistic Missile Defense Organization (BMDO)	Sponsor for the National Test Facility (NTF)
Air Force Training System Program Office (SPO)	Sponsor of Project 2851 (Standard Simulator Database Program)
Commander Marine Corps Systems Command	Sponsor for MTWS. Marine Corps agent for research, development, and procurement.
Commanding General Marine Corps Combat Development Command (MCCDC)	Sponsor for modeling and simulation within the Marine Corps.
Army Training and Doctrine Command (TRADOC)	Army DIS functional manager. Army DIS VV&A proponent.

Table 2-2. DIS Supporting Agencies

AGENCY	ROLE
Advanced Research Projects Agency (ARPA)	Developer and Manager of the Defense Simulation Internet (DSI)
Defense Information Systems Agency (DISA)	Will Assume Control and Manage DSI, DoD Agent for Developing Information Systems Standards
National Security Agency (NSA)	Developing Security Procedures for DIS. Developing Encryption/Decryption Technology Usable by DIS
Defense Industry	Developing Reusable Hardware/Software Systems for Use In DIS

programs committed to using the DIS standard and indicates the extent to which the standard will be implemented.

2.4 Related Planning Efforts

Several general planning efforts are underway which address DIS standards in one form or another. To optimize the application of DIS standards, these standards and the DIS planning efforts must be coordinated at least to the extent that each is aware of the other's goals and primary functions. Only by maintaining liaison with other planning efforts can the DIS community prevent the misunderstanding of DIS goals, misapplication of the standards, and unrealistic expectations.

A planning effort closely associated with this one is the Synthetic Environment Strategic Plan developed by DMSO. That plan focuses primarily on Advanced Distributed Simulation applications. That is, the plan defines programs, outlines the roles of agencies involved, addresses funding issues, advocates expansion of ADS, and identifies new opportunities. This Vision document, in contrast, is intended to define the supporting infrastructure needed by ADS programs.

Table 2-3. Primary DIS Users

USER ORGANIZATION	UTILIZATION
Entertainment Industry	Development of Interactive Games & Recreational Simulations for Multiple Users at Distributed Locations
Defense Industry	Testing Effectiveness & Interoperability of Systems During Early Design & Prototype Stages
Military Services	Platform & Unit Training, Mission Rehearsal, Tactics Development/Evaluation, Testing Effectiveness of Weapons Systems at the Conceptual, Developmental, Prototype & Operational Test Phases, Force Structuring Analysis
Department of Transportation (DOT)	Testing Effectiveness, Compatibility, & Interoperability of Transportation Systems at the Conceptual, Developmental, Prototype & Operational Test Phases. Potential for Use in Licensing & Certification of Public Vehicle Operators
Federal Aviation Administration (FAA)	Individual & Team Training (future), Testing Effectiveness, Compatibility, & Interoperability of Aircraft & Air Traffic Control Systems At The Conceptual, Developmental, Prototype & Operational Test Phases
National Aeronautics & Space Administration (NASA)	Platform & Unit Training, Testing Effectiveness of Aircraft & Space Systems At The Conceptual, Developmental, Prototype & Operational Test Phases

The Army is sponsoring the development of a DIS Master Plan and a DIS Modernization Plan. Both of these plans are in early stages of development and only the general information about them is available.

The DIS Master Plan conveys the user's vision of the DIS synthetic environment, establishes the relative importance of its elements, assesses current DIS capabilities, and sets priorities for submitted requirements. It identifies key players and the managerial structure for DIS and identifies roles and responsibilities for the key players. The master plan will be used to define processes necessary to achieve the vision, to organize collective efforts of DIS, and to guide the allocation of resources.

The DIS Modernization Plan provides a quantified resource constrained implementation road map, describes the Army investments for DIS, identifies non-Army money to leverage DIS growth opportunities, and documents continuing assessments of DIS capabilities. The Modernization Plan will be used to establish policy and direction for Army DIS investments, determine DIS core investments, identify DIS investments in other programs, and to build and maintain the DIS core and Modernization Development Plan (MDEP).

2.5 Time Frames

The estimates of what capabilities DIS will have in the future have been separated into three time increments; two years, five years and out years. These time increments were chosen because most government organizations do their budgeting and planning in detail for two years, with less detail for five years and make long range plans for out years.

2.6 Planning Process Used

This document is to serve as both a vision for the future of DIS and as a map that outlines the paths that may, and sometimes must, be taken for the vision to become reality. The process used in developing this document follows techniques used by business and non-profit organizations for long range planning. The process consists of the following basic steps.

a. Set general goals and guidelines for the planning process.

b. Define the mission of DIS

c. Identify and examine factors which threaten future development and strengths within the DIS community that can counter these threats.

Table 2-4. Programs Committed to Using DIS Standards

PROGRAM	DIS IMPLEMENTATION
Close Combat Tactical Trainer (CCTT)	Provide virtual environment and communicate states and interactions of forces at distributed locations (will use all components of DIS standard set)
Tactical Combat Training System (TCTS)	Communicate states and interactions of forces in TCTS for interactions with other forces in a DIS exercise (extent of DIS application TBD)
Battle Force Tactical Trainer (BFTT)	Communicate states and interactions of forces in BFTT for interactions with other forces in a DIS exercise (extent of DIS application TBD)
High Dynamics (HY-DY)	Communicate states and interactions of virtual aircraft for display and targeting on live aircraft fire control system (extent of DIS application TBD)
National Simulation Capability (NSC)	Examine the effectiveness, compatibility and interoperability of new aircraft and ATC systems, technologies, and operational concepts." (extent of DIS application TBD)
WarBreaker	Provide system engineering tool to evaluate alternative approaches for prosecuting time critical targets (uses DIS communication between internal subsystems)
Combined Arms Tactical Trainer (CATT)	Provide series of simulation programs (encompasses CCTT) sponsored by STRICOM (will use all components of DIS standard set)

Table 2-5. Planning Concerns & Possible Countermeasures

CONCERN	COUNTERMEASURE
Conflicts with other standards groups	Make it clear that we will use existing standards where possible. Actively pursue identification of potential conflicts. Establish process to mediate unavoidable conflicts. Participate in related standards development activities.
Power struggles between component groups	Plan will help define turf boundaries. Keep potentially conflicting interests in the review process. Find representatives of threatened interests and bring into DIS community.
Plan may not meet expectations	Make sure that people with potentially unrealistic expectations are part of the plan review process. Call special conference/workshop for high level review of plan.
Assumptions may not be accurate	Get inputs from outside of planning group. Plan & conduct comprehensive review of plan. Revise plan to reflect confirmed or refuted assumptions.
Technology advancement may make plan inaccurate	Build decision points into the plan. Have recurring review of plan after it is implemented.
Projections may be unsupported	Carefully document and justify projections in the plan. Maintain good references.
Plan may not cover entire user community	Define carefully who the user community is and allow for expansion as interest increases. Use industrial organizations to reach intended community.
How to make DIS more attractive to the non-DoD user	Be aware and conscious of current DoD orientation. Invite non-DoD organizations to participate. Publish DIS activity outside the DoD community.
Plan may not be comprehensive enough	Carefully define the scope of the plan. Define "exit criteria." Solicit plan input from DIS working group chairs. Ensure that plan addresses both DIS and workshop user.

d. Identify opportunities in which DIS can grow and prosper.

e. Establish goals and define specific, measurable objectives to support those goals.

f. Continually review and refine the goals and objectives.

2.7 Concerns and Countermeasures

Any planning process tends to be controversial because, to be effective, the process must examine weaknesses and identify threats. Real and potential concerns expected in the DIS planning process, along with recommended countermeasures, are identified in Table 2-5.

SECTION 3

UNDERLYING TECHNICAL APPROACH

Although a detailed explanation of the DIS architecture is beyond the scope of this document, it is worthwhile to summarize briefly some of the fundamental technical approaches and assumptions on which all DIS standards are based. These date from the early years of the DARPA SIMNET program, which began in 1983.

3.1 DIS Design Principles

Object/Event Architecture. Under this principle, information about non-changing objects in the virtual world is assumed to be known to all simulations and need not be transmitted. Dynamic objects keep each other informed of their movements and the events that they cause through the transmission of PDUs.

Autonomy of the Simulation Nodes. From the standpoint of an individual simulation node, all events are broadcast and are available to all interested objects. The node at which the event was caused does not need to calculate what other nodes may be interested in that event. It is the receiving node that is responsible for calculating the effects of an event on the entities it is simulating and determining whether or not the event is meaningful. These effects may include the generation of new events, as was previously noted. The autonomy principle enables nodes to join or leave an exercise in progress without disrupting the simulation.

Transmission of "Ground Truth" Information. Each node transmits the absolute truth about the state of the object(s) it represents. The receiving nodes are solely responsible for determining whether their objects can perceive an event and whether they are affected by it. Degradation of information (which is essential for realistic portrayal of system behavior) is performed by the receiving node in accordance with an appropriate model of sensor characteristics before it is presented to human crew members or automated crews.

Transmission of State Change Information Only. Under this principle, nodes transmit only changes in the behavior of the entities they represent. This is designed to minimize the unnecessary transmission and processing of data. If an entity continues to do the same thing (e.g., straight and level flight at a constant velocity), the update rate drops to a predetermined minimum level.

"Dead Reckoning" Algorithms to Extrapolate State Information Between Updates. Each simulation node maintains a simplified representation of the state of nearby entities, and extrapolates their last reported states until the next state update information arrives. The nodes representing each entity are responsible for transmitting new state information before the discrepancy between its "ground truth" information and the extrapolated approximations being generated by the other nodes becomes too large.

In essence, this dead reckoning approach requires a "contract" between the simulation nodes, in which they guarantee the accuracy of an extrapolation of their previous data, and transmit new data that can be used to initialize a new extrapolation before a previously agreed-upon threshold is violated. This means that each node must maintain a dead reckoning model of its own objects that corresponds to the model(s) being used by all other nodes, and that it must continuously compare its "ground truth" information with the approximations being used by the other nodes. When a state update is transmitted, it includes not only the correct position and orientation but also the velocity vectors and other derivatives that can be used to initiate a new extrapolation.

Simulation Time Constraints. Current DIS standards primarily support human-in-the-loop simulations. General experience in the real-time simulation community indicates that humans cannot distinguish differences in time less than 100 milliseconds. This has been the basis for currently published DIS performance standards (e.g. communications latency). Interactions between real weapon systems, sensors, and tactical communications links generally occur at much faster rates (e.g. less than one millisecond). DIS standards may be used to support these interactions provided that their latency requirements can be met by the communications subsystem.

Event driven simulations (e.g. wargames) often move faster or slower than real time. The intervals at which the states of all the participants are updated may be irregular and minutes may elapse between them. Because of the humans in the loop, DIS assumes that exercise time corresponds with the actual progression of time. Interfaces with event-driven simulations will require a

mechanism to provide "public" data at real time rates. "Public" data includes all entity state and other data defined in the PDUs.

However, care must be taken to ensure that the network and the DIS PDUs are able to support all DIS-based applications participating in a common exercise. Due to inherent communications latency, geographically separated sites may not be appropriate for the faster rate of interaction between weapon systems but may be quite appropriate for the interaction between constructive and virtual simulations.

3.2 Communications

The above principles are implemented via the exchange of information between the nodes. The information is carried in packets called PDUs, that are defined as part of the interface standard. These PDUs may be carried on any logical links that connect the nodes. In practice these links are part of a network structure. Simulation nodes located at the same site are connected by a Local Area Network (LAN). If different simulation sites are to be part of the same DIS implementation they are generally linked by high speed data lines that connect the LANs at each site, thereby creating an *ad hoc* Wide Area Network (WAN) for that particular application. Sites may also be linked by the Defense Simulation Internet (DSI), a general purpose, high speed, common WAN being developed by DoD in part to serve DIS-based applications.

To understand some of the communications issues associated with DIS, one must examine the key interfaces in the network structure.

Figure 3-1 illustrates the interface between the simulation host computer and its LAN. Note that entity state PDUs represent the majority of the network traffic. In electronic warfare (EW) applications, Emission PDUs are expected to produce almost as much traffic. Voice communication/tactical data link PDUs are the next greatest component. Weapons fire and detonation PDUs also contribute a significant amount of traffic. All other PDUs account for the remaining small fraction of the total.

Currently incoming PDUs at the simulation node interface vastly outnumber the outgoing PDUs, usually by a much larger ratio than is shown in the diagram. In any but the most simple applications, a network interface processor screens these PDUs, and passes on to the simulation host only those that meet the criteria specified by the host as being most relevant to the entities it is simulating. Without this screening, a much more powerful simulation host processor would be required to avoid being overwhelmed with data traffic.

The situation depicted in figure 3-1 assumes a broadcast mechanism that sends all PDUs on the entire network to each simulation node. In large DIS-based applications this amount of traffic would overwhelm even the best available network interface processors. To cope with this, some sort of data traffic control is needed. The most elementary of such traffic control mechanisms

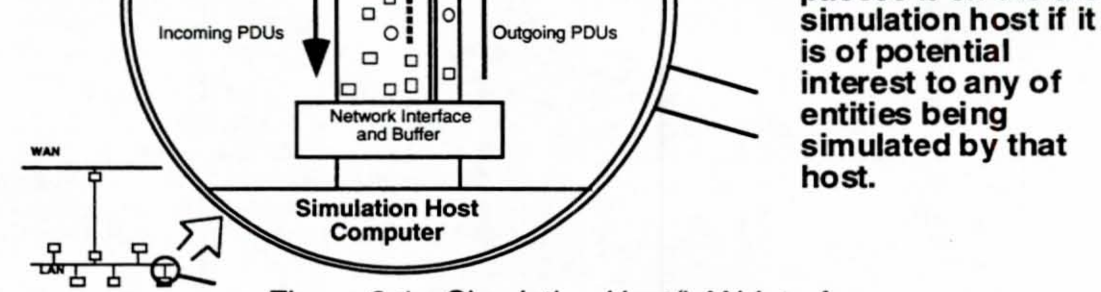

Figure 3-1. Simulation Host/LAN Interface

is multicast addressing. Rather than broadcasting all PDUs, a grouping algorithm ensures that those PDUs that are relevant to a particular simulation host are received by it. These multicast groups may be based on exercise ID, proximity in the virtual world, organizational hierarchy in the virtual world (e.g. same battalion), PDU type (e.g. entity state vs. emission), fidelity requirements (e.g. low fidelity entity state PDUs in a separate group), or some other criteria. Of even greater importance, multicast transmissions to which none of the entities on a particular LAN have subscribed need not be transmitted to that LAN at all. The next two figures illustrate this concept.

Figure 3-2 shows the interface at which the local area network interfaces to a WAN. At this interface, data compression and packet aggregation can be employed. For most applications, this is also the logical place for encryption to occur. Usually the local area network can be physically secured, and end-to-end encryption can be employed for the journey of the data across the WAN. The LAN gateway is also responsible for apprising adjacent WAN nodes of the set of multicast groups to which its simulation nodes have subscribed.

Figure 3-3 shows the WAN gateway. In the illustration, the WAN is shown as a linear backbone, but the principles described here are equally relevant to other topologies. The WAN gateways are responsible for real-time negotiation of network bandwidth reservations, where they are adjustable, and for ensuring that the right multicast traffic is forwarded to the LAN gateways that have requested it.

3.3 Environment Correlation

We speak of a single unified synthetic environment in DIS. This is an abstract notion that makes it convenient to discuss various DIS issues. In the implementation of DIS, however, each connected simulation application creates its own copy of the common environment. Each application modifies this environment based on information it receives from the other applications to which it is connected. For a variety of reasons, these copies differ from each other. That is, they do not correlate perfectly These imperfections may be insignificant or they may be so extensive as to render the entire simulation useless. The degree to which the copies of the environment correlate with each other is one of the major issues facing the DIS community.

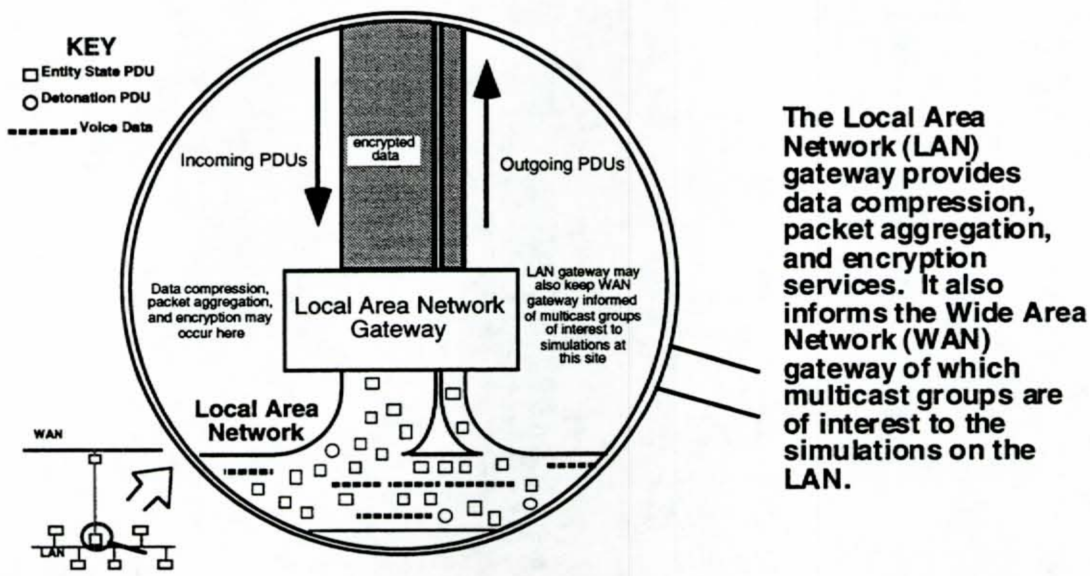

Figure 3-2. LAN/WAN Interface

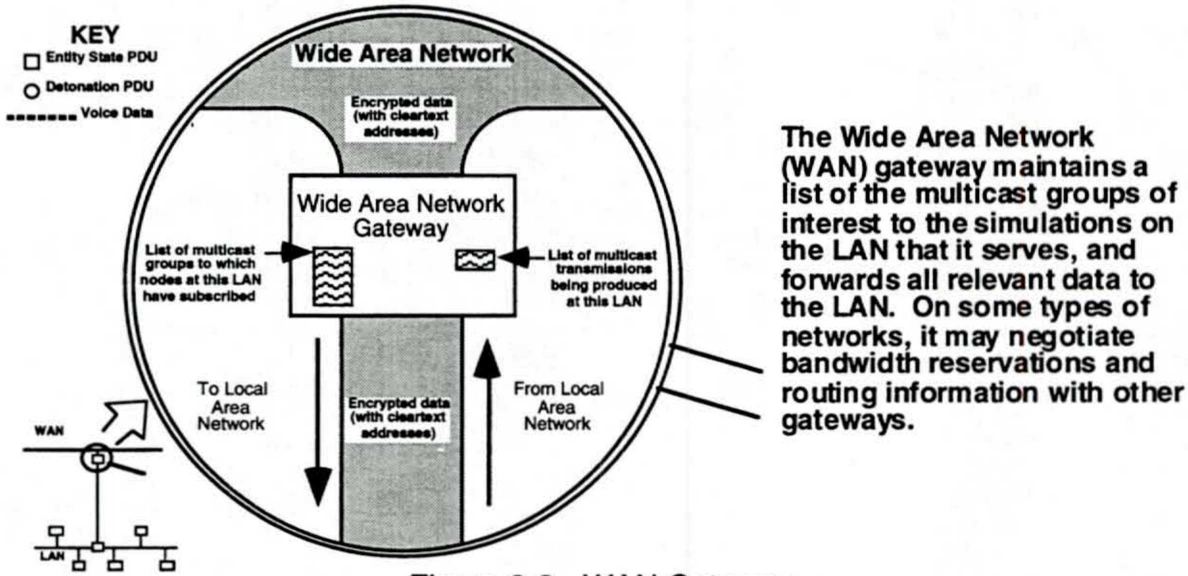

Figure 3-3. WAN Gateway

A method of envisioning correlation within DIS is to consider correlation as being divided into three domains, each domain having influence over correlation, and the consistency and realism required of DIS events. Each domain has unique functional characteristics. Figure 3-4 illustrates the domain paradigm and includes several characteristics of each domain.

"Appearance-How it Looks" is independent of spectra, sensor, or type of simulation (virtual, live, or constructive). Appearance can be a first-order, 3-D, out-the-window human visual cue; it can be a second order, 2-D, through-instrumentation cue on a flat screen display; it can be a third order, Boolean term (yes/no) derived through ECM/ECCM logic. Objects within the environment can "appear" to the human eye, human ear, haptic (skin) senses, proprioceptors (body part position), sensor apertures, RF receivers, or CGF intervisibility test algorithms. The use of the term "perception" carries with it the baggage of human experience and intuitive cognition, characteristics of a human operator when interfacing with all three domains. Humans can

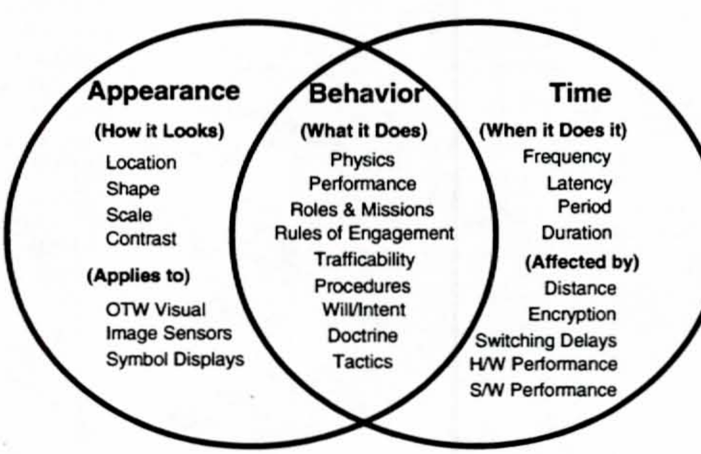

Figure 3-4 DIS Correlation Paradigm

perceive correlation differences in appearance, behavior, and time.

"Behavior" is the middle-man, and serves as the domain indicator of how "appearance" changes over "time."

Correlation of DIS synthetic worlds is a very complex issue. What may be adequate in one exercise or one circumstance may not be adequate in another. The purpose of the exercise is also very important. The same exercise executed for different purposes will likely have different correlation requirements. The understanding of such correlation requirements is central to the whole VV&A process. This issue is examined further in section 6.3.

SECTION 4

DIS STANDARDS DEVELOPMENT MECHANISM

4.1 Structure of DIS

The structure behind the DIS movement is unique and a bit difficult to describe. There are no articles of incorporation, charters, bylaws, organization charts, parent organizations, or other elements typical of an organization. What organization there is, is modeled after industry standards development efforts. That is, groups of volunteers gather periodically, do research, debate relevant issues, form consensus, and publish standards. These groups are self-directed and self-governed.

The DIS workshops and the overall standards effort are coordinated and supported by the University of Central Florida's Institute for Simulation and Training (IST) with funding initially from the Defense Advanced Research Projects Agency (DARPA) and currently from STRICOM and DMSO. The bulk of the standards development work is done by volunteers provided by contractors, government agencies, and academic bodies that have interests in modeling and simulation.

4.1.1 Workshops

The center of the standards development effort is a series of semiannual workshops held in Orlando each March and September (by tradition). These workshops serve a number of purposes:

- Forum for the debate of major issues
- Presentation of general information on new programs and overall direction of DIS
- Tutorial information for newcomers
- Feedback on use of the standards at an "Implementer's Workshop"
- Exposure of new ideas via a series of special interest sessions
- A meeting place for technical working groups

The current work on standards began in August 1989 with the first workshop. The number of participants at the workshops has grown steadily (Figure 4-1).

4.1.2 Technical Working Groups

The corps of volunteers are organized into technical working groups and subgroups to handle specific areas of the standards. The number and structure of these groups and subgroups are fluid to respond to new requirements for standards as they emerge. *Ad hoc* groups, usually called "tiger teams," are frequently formed to handle special projects. Special Interest Groups (SIGs) are formed to handle new areas and may, or may not, become new technical groups. Membership in the technical groups is informal and open. Individuals may belong to as many or as few as desired. Each group is led by a chair chosen by the group. About 30 groups, subgroups, and SIGs met at the March 94 workshop. Many of the technical groups hold interim meetings between workshops at a site and time mutually agreed upon. Much of the work is also done via teleconference and electronic mail.

4.1.3 Steering Committee

The overall standards development effort is coordinated by a DIS Steering Committee. The Steering Committee has three components: Technical Committee, Sponsor/User Committee, and the Coordinating Com-

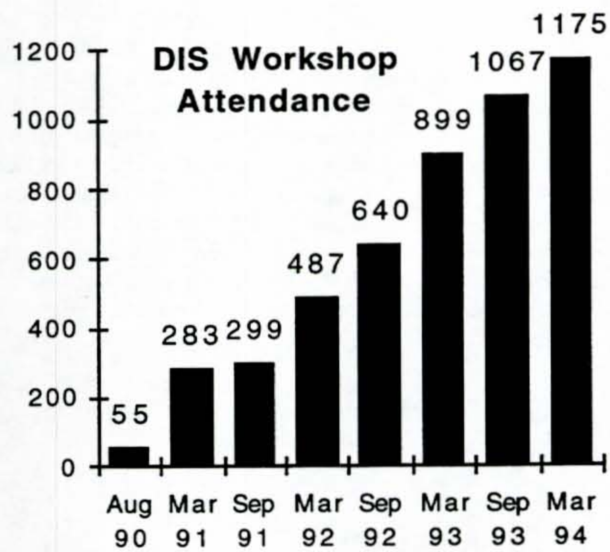

Figure 4-1. Workshop Participation Grows Steadily

mittee. Subgroup and working group chairs make up the bulk of the Technical Committee. Representatives from key funding organizations, the government, and non-DoD users of DIS make up the Sponsor/User Committee. The Coordinating Committee consists of 8-10 individuals who work to coordinate the efforts of the other committees.

4.1.4 Standards Development Process

The development process differs from one technical group to the next. Generally each group decides where standards are needed within its area of responsibility. Often standards are needed in areas that overlap different technical areas. When such needs are recognized the technical groups meet in joint session or create a team with members from several groups to handle the situation.

The standards themselves are based on papers presented to the group and subsequent discussion of the issues. An initial draft of the standard is created by volunteers from within the group and is presented and refined in subsequent meetings. When the Technical Committee is satisfied with the content and format of its standard, it forwards the draft to the Steering Committee.

4.1.5 Approval/Review Process

The Steering Committee reviews the document and may send it back to the Technical Committee for revision or may submit it to the IEEE for formal approval. The heart of the IEEE approval process is the formation of a balloting group and voting process. For DIS standards the balloting group consists of members from industry, academia, and government that are associated with DIS. Members of the balloting group may recommend changes to the standard in conjunction with their votes. Such recommendations are formally considered by the technical committee that originated the standard and are incorporated to the extent possible to ensure approval of the standard on subsequent ballots.

During this IEEE standards approval process, the workshops continue and extensions to the standards that incorporate expanded capabilities are developed. These extensions will also be submitted to IEEE for approval.

4.2 Relationship of SIMNET and DIS

Between 1983 and 1989, the Advanced Research Projects Agency (ARPA), formerly DARPA, successfully demonstrated the core technology for networking large numbers of manned simulators, emulators, and computer generated forces (CGF). The SIMNET R&D project distributed simulations at eleven sites in the U.S. and Europe and included ground combat vehicle simulators for the M1 Abrahms main battle tank and M2 Bradley Infantry Fighting Vehicle as well as a small number of fixed and rotary wing aircraft simulators and up to a thousand vehicles controlled by CGF.

SIMNET consisted of a set of homogeneous components built specifically for that project. In an effort to expand the use of the technology, DIS standards are being developed to provide industry wide standards to enable the linking of heterogeneous systems. In an early workshop, it was decided to use the SIMNET concepts as a basis for development of the initial DIS standard protocols. Subsequent workshops have both refined the initial interface protocols and extended the standards into other areas required for interoperability such as communications, environment, management, and security.

4.3 Status of Standards

DIS standards are organized into the series of documents, each of which covers a different aspect of interoperability. The status of each is outlined in Table 4-1. Other potential standards include: Field Instrumentation, DIS Architecture, Common Database.

In addition to the standards, the technical groups produce rationale documents that provide backup information for their associated standards and, in some cases, also provide general guidance documents to assist designers in building DIS compatible components.

Table 4-1 DIS Standards Status

ID	TITLE	PURPOSE	STATUS
IEEE 1278	Standard for Information Technology - Protocols of Distributed Interactive Simulation Applications, Version 1.0	Provides basic interface definitions including data formats and PDUs.	Approved by IEEE (March 93).
IST-CR-94-50	Standard for Information Technology - Protocols of Distributed Interactive Simulation Applications, Version 2.0 Fourth Draft	Adds PDUs for emissions, voice, data link, and management.	Being submitted to IEEE.
IST-CR-93-46	Enumeration and Bit Encoded Values for Use with Protocols for Distributed Interactive Simulation Applications	Provides enumeration and bit encoded values for PDUs.	Being updated by IST.
IST-CR-94-15	Communication Architecture for Distributed Interactive Simulation (CADIS)	Defines required communications services, protocols, and performance.	Being submitted to IEEE.
IST-CR-94-13	Fidelity Description Requirements for Distributed Interactive Simulation	Provides fidelity description requirements.	Initial draft in technical group.
IST-CR-94-12	Exercise Control and Feedback Requirements for Distributed Interactive Simulation	Provides exercise control and performance measures feedback requirements	Being submitted to IEEE.

4.4 DIS Demonstrations

The DIS PDU standard and the communication architecture standard got their first major test at a demonstration of distributed simulation at the 1992 Interservice/Industry Training Simulation and Education Conference (I/ITSEC) in San Antonio. The I/ITSEC is the training and simulation community's major annual gathering. Part of the conference is a large trade show to which all the major modeling and simulation contractors bring their wares. In the past all the simulators demonstrated did so on a stand-alone basis. During the 1992 show 30+ simulators, computer generated force devices, and monitoring devices, from 20+ organizations were linked together on an Ethernet LAN using the basic DIS PDUs. The virtual world consisted of a military base near the Pacific ocean (Fort Hunter-Liggett) and the adjacent waters. The scenario included maritime, air-to-air, air-to-ground, ground-to-air, and land operations in which all the players took part. The 1993 version of the demonstration featured 50 simulators from 30+ organizations and included participation by live units and simulators from remote sites. These demonstrations were very successful and have become the centerpiece of the conference.

Since 1992, the DIS PDU standard (and most of the CADIS standard) have been demonstrated numerous times. In 1993, the BDS-D program demonstrated a DIS interface between the Crew Station Research and Development facility (CSRDF) in San Jose, CA and the Aviation Test Bed (AVTB) at Ft. Rucker, AL. At the Association of the United States Army (AUSA) Louisiana Maneuver's Symposium in May 1993, the DIS demonstration involved simulators and stealth vehicles in Orlando, FL connected via a WAN to simulators located at CSRDF, the AVTB and in Stratford, CN. WarBreaker demonstrated a number of developing DIS capabilities including radio communications.

These demonstration proved the viability of linking simulations of different types, based on different technologies, and built by different organizations. They also provided a wealth of experience that is being fed back into the standards development process.

SECTION 5

CURRENT STATUS AND ASSESSMENTS

The section presents a snapshot of the current status of DIS technology. This is accomplished by describing DIS in three key areas: demonstrated strengths, current challenges, and past and on-going programs and applications.

5.1 Strengths of DIS

Simulation and modeling have long been used for training, analysis of systems, and system testing. While many current applications are military, this is not a limiting factor.

- Simulation and modeling clearly have application to civilian agencies such as the National Aeronautics and Space Administration (NASA) and the FAA.
- Their use in the entertainment industry for amusement parks, video games and motion pictures is growing rapidly.

DoD has identified Synthetic Environments as a major science and technology thrust. It envisions the use of computers, networks, world wide terrain, and Hollywood special effects to model joint theaters of war with very large combat forces. It provides a challenging motivating combat situation requiring total immersion by war fighters to create, refine, practice and master joint doctrine. It plans on using fully distributed simulations to make this concept affordable. DIS is the backbone of this thrust.

5.1.1 Government Support

As indicated in the following quotes from recent presentations and speeches by military leaders, the defense community has enthusiastically adopted DIS:

"Simulation is fundamental to readiness"(Gorman)[4]

"Distributed Interactive Simulations hold great promise for compressing the acquisition cycle and removing much of the frustration from our acquisition system. Simulation lets us see and touch the acquisition cycle. I believe we can collectively help change our heel-toe cold war system to a more responsive - and more cost-effective - process."(Sullivan)[5]

Each service currently has its own simulations and models. In many cases these models can be connected through DIS technology to provide "jointness" in exercises at a much lower cost than developing totally new simulations.

Congressional interest in and support of DIS has also been very strong. DARPA's 73 EASTING demonstration used distributed simulation technology to recreate a major tank battle of Operation Desert Storm for the Senate Armed Services Committee on May 21, 1992. Players at multiple locations in the United States were linked together to produce a demonstration in the Senate Armed Services Committee Room. Dr. Hamre, of the Senate Armed Services Committee staff, clearly expressed this congressional support in his keynote speech at the Seventh Workshop in March 1993:

"... Senator Nunn is one of the leaders, along with Senator Warner, Senator Cohen, Senator Levine and others who see the power of this new technology..."[6]

"[It is seen as] one of the few tools that can keep alive an invigorated energy to carry the Defense Department through a dry spell"[7]

"the modeling and training methodology that the Army has perfected during the last ten years... is transferable to the world of disaster and emergency preparedness...Architects, engineers, and designers can also benefit."[8]

The FAA has joined the DIS standards development effort and sponsors a SIG within DIS devoted to the FAA's needs. FAA representatives have indicated the FAA's intent to use DIS standards on the agency's NSC program.

5.1.2 Industry/Academia Support

As the potential of DIS becomes clear, more and more players are participating in various DIS activities. All of this participation is at their own company's or agency's expense. Attendance has increased at each workshop. Representatives of numerous government agencies, more than 150 different companies, and at least 12 foreign countries have participated in DIS Workshops.

Twenty companies participated in the 1992 I/ITSEC Demonstration. This highly successful demonstration required participants to attend monthly planning meetings and to spend two weeks in San Antonio setting up

and participating in the demonstration. All participation was voluntary. It required a high degree of cooperation between competitors.

> *"It was a team event we all planned, we the companies who were involved. We planned the event; we weren't told what to do or how to do it and we wound up helping each other achieve a common goal."[9]*

Increased attendance at the DIS workshops along with greater participation in DIS demonstrations supports the idea that industry is increasingly supportive of DIS and its potential. Also on the increase are academic conferences which address DIS topics.

5.1.3 Open System Approach

The DIS standards are developed in an open forum. All interested parties are free to participate as the various Working groups develop standards. After standards are adopted by a working group they are approved by the Steering Committee and balloted by the IEEE. This process assures that each DIS standard is *"a public specification that is maintained by open, public consensus process to accommodate new technologies over time and that is consistent with international standards." (IEEE 1991.)[10]*

The open systems environment assures that a wide variety of technical expertise based on experience with many potential uses is available to develop the standards. The consensus process allows potential users and implementers to point out their individual needs and achieves "buy in" by the concerned parties. Since the standard is publicly available it can be adapted for use beyond the defense community. New ideas and needs are introduced into the process as they are identified during the continuing workshops.

> *"And that's really what open systems environments are all about...is trying to establish those architectures and standards that the individual markets work in a very cost effective manner and still take great advantage of that competitive and creative commercial market that we have."[11]*

5.1.4 Built on Proven Foundation

While DIS is relatively new, it is based on 10 years of experience with SIMNET. This DARPA/Army program showed that independent simulators could be interconnected in a manner that allowed them to operate in the same virtual world. It demonstrated a capability for low-cost team training. A DARPA War Breaker Demonstration in 1992 extended the use of these protocols to connect dissimilar Army, Navy and Air Force simulations. The protocols in version 1.0 of IEEE Standard 1278 are based on similar protocols used in SIMNET. Further extensions of DIS protocols will build on this firm foundation.

DIS also builds extensively on existing standards.

- The communications architecture is currently based on the Internet Protocol Suite, Transmission Control Protocol/Internet Protocol (TCP/IP) and uses existing services. As OSI protocols progress and become commercially available, the communication architecture will migrate to these internationally accepted standards with the end goal of becoming Government Open Systems Interconnection Profile (GOSIP) compliant.
- A North Atlantic Treaty Organization (NATO) Standardization Agreement (STANAG) requires use of DIS to interconnect Level I (individual and crew training) devices and Level II (tactical training) devices developed by and located in different NATO nations.
- Standard Interchange Format developed by Project 2851, the DoD Standard Simulator Data Base Program, is the only available mechanism to achieve common terrain data bases among dissimilar simulators. Its use was demonstrated at the 1992 I/ITSEC Demonstration.

Government agencies and Congress clearly recognize the current and future value of DIS, assuring budget support. The defense industry sees DIS as a growing business area in an era of austerity. Academia, commercial agencies, civilian agencies, and the international community are beginning to recognize its potential. DIS is based on extensions to currently available, demonstrated technology and standards. The open systems architecture assures that their efforts will work together to achieve a common goal.

5.2 Challenges

Although DIS has been successful to this point, the movement is currently facing a number of technical, programmatic, and user-perception challenges that must be overcome for DIS to reach its full potential.

5.2.1 Comprehensive Architecture

Foremost among the technical challenges is the design and promulgation of a comprehensive architecture. The architecture must be comprehensive in the sense that it meets the following criteria:

- Serves the needs of the three major "theaters" of DIS-based applications: virtual, constructive, and live
- Provides design guidance for the linking of these application domains into "seamless simulation" exercises that can be validated
- Provides design guidance to support backwards compatibility with existing DIS-based applications.

Most architectural schemes for DIS have evolved in an *ad hoc* fashion. A few explicit architectures have been developed and put forward as attempts to address the requirements and needs of all DIS technology. However none of these architectures have to date garnered community-wide acceptance and implementation.

Establishment of a comprehensive architecture that can shape the design and implementation of DIS, bring order to the emerging standards, and establish common terminology and conceptualization will only come about through the avenues of DIS-community involvement and acceptance. For this reason, opportunity exists for the DIS Interoperability Workshop, leveraging off of its widespread participation and acceptance, to promulgate the common architecture. The Interoperability Workshop can be the most efficient forum for gaining consensus on these issues. The process is best accomplished by evaluating the existing architectural approaches and selecting and integrating the best designs.

5.2.2 Correlation of Environments and Entity Models.

Key to the utility of DIS is its capability for combining simulators, constructive simulations, and stimulated equipment of varying type, origin, and performance into joint simulation exercises to realize a common synthetic environment. DIS technology uniquely offers this potential. Yet the success of these joint endeavors hinges on the acceptable correlation of environments and entity models. Figure 5-1 illustrates the scope of the problem.

There is an additional dimension to the problem of interoperability, namely the significant variation of exercise objectives and thus exercise unique correlation and fidelity requirements. What qualifies as interoperable for one set of exercise goals may be rendered inadequate by changing the set of goals. It should be noted that these goals are also difficult to define at the time the

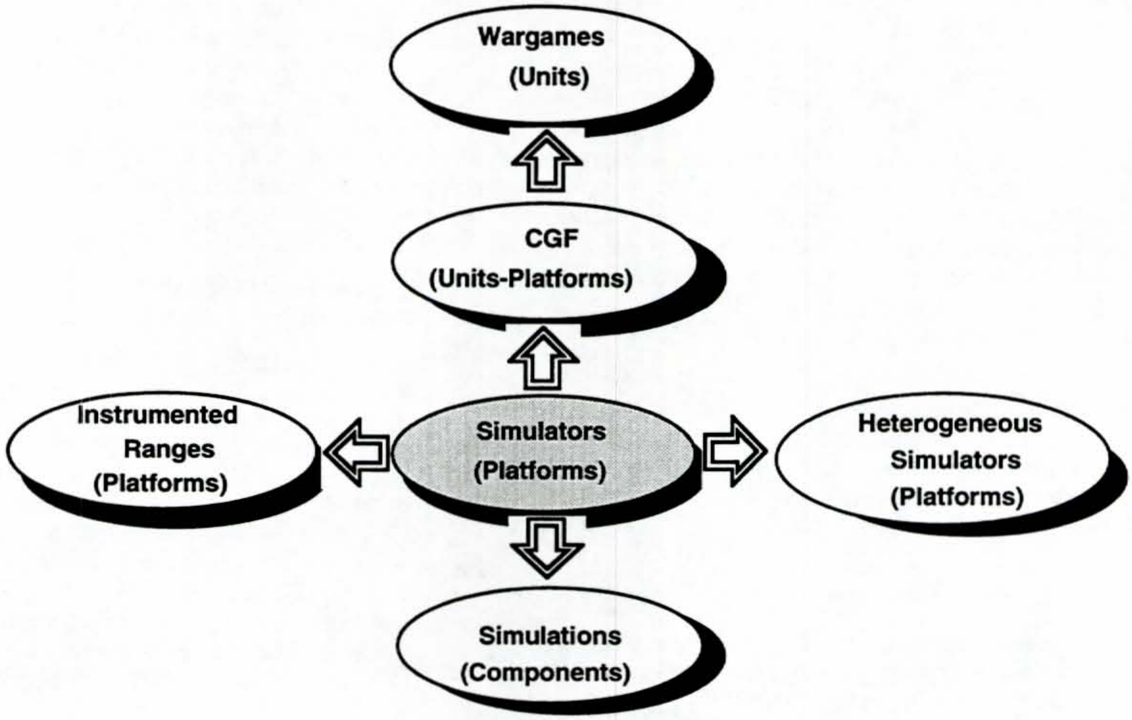

Figure 5-1. Correlation of Environments

simulation assets are built. Two key concepts help to explain this issue.

First is the concept of interoperability. Before one can consider joint operation, there must be in place standards for communication to enable entities to register their interactions with the synthetic environment. This need is satisfied by means of a standard for entity definition and entity communication. This is the job of the DIS protocol.

Interoperability, however, presents merely an initial capability for joint usage. Utility of DIS comes from consideration of the fair fight. Here one is concerned with the correlation of outcomes in simulation with outcomes in the real world. In the midst of a simulation exercise, there is no one synthetic environment (except in the ideal). Each simulator, constructive simulation, and stimulated system produces its own view of the synthetic environment — tailored to the performance and capability of that particular system. Differences can abound — differences in terrain database, vehicle models, lines-of-sight, network capacity, target acquisition, weapon performance, etc. When these differences contribute to a departure of simulation outcomes from real-world outcomes, then they adversely impact the fair fight. The fair fight is also vulnerable to network-related problems such as latency, dropped packets, and out-of-sequence deliveries.

To remedy these problems, DIS technology needs to solve the basic problems of correlation of time and space in the synthetic environment. Standards against the database and network need to be promulgated, methods for configuration management and distribution of databases need to be invented, and technical problems concerning lines-of-sight, image generator overload, and others need to be solved. Verification and validation methods must be developed in order to determine the fidelity and utility of synthetic environments to the intended applications.

Many of these problems have been solved and the solutions demonstrated on a case-by-case basis. Standards efforts are progressing with the maturing technology. However, this area will continue to require solutions and systematic development for DIS to continue to mature.

5.2.3 Long Haul Network Access

To unleash the potential of DIS technology for diverse applications, one requires the flexibility to connect far-flung sites and equipment to support rapidly reconfigurable exercises. The key requirement here is affordable and effective long haul access.

Communications is one of the most rapidly evolving industries today. Fiber-optics, high speed switching, low earth orbit communications satellites, and dial-up high bandwidth service are major technologies applicable to DIS communications. While DIS can use many products and services from the commercial communications industry, it has several unique requirements that are not being addressed by commercial services and products. These are:

Low Latency. To adequately simulate the interaction between simulated high performance crewed platforms and to simulate tactical voice radio networks, the CADIS standard establishes maximum latency standards of 100 milliseconds (between closely coupled entities) and 300 milliseconds (loosely coupled). This latency standard refers to maximum amount of time allowed for a PDU to travel from its transmitting application to every receiving application no matter where the applications are located. This is a much more stringent requirement than those encountered in conventional communications applications.

Multicast Addressing. A fundamental design philosophy of DIS is that each simulated entity tells all other simulated entities of its own activity. It does so without knowledge of who the other entities are or what their capabilities are. To handle such many-to-many communication the underlying network must support multicast addressing. Most commercial communications are built around the point-to-point addressing of the telephone model. Some multicast development work is being done to support video and telephone conferencing.

The DIS community is approaching these requirements with two thrusts:

Defense Simulation Internet (DSI). This is an ARPA sponsored development to create a high capacity, general purpose, packet switching wide-area network (WAN) with enough performance to support distributed simulation. Although its planners expect it to be able to support DIS-based applications, it is not being designed to meet specific CADIS standards. DSI has evolved from previous ARPA network developments and is currently functioning as a test bed for key technology upgrades. For this reason its ability to meet operational requirements is limited. The cost to access DSI is $150-300K per node per year.

Ad Hoc **Networks.** This is simply a collective term to describe networks that various projects or agencies have created to support specific distributed simulation applications. The structure, capabilities, and costs of these networks vary widely. The benefits of this approach are that the networks can be tailored to meet specific requirements and costs can be directed at a specific application in contrast to supporting a general infrastructure, which may, or may not, provide the services required. Such networks are generally under the direct control of the user and he has access to all capabilities. The primary drawback to this approach is that the user must devote many of his resources to creating a supporting infrastructure (e.g. communication) at the expense of his primary application (e.g. simulation). Such networks are usually not interoperable.

Whether DSI matures to the point that it can cost- effectively support all DIS-based applications or whether *ad hoc* networks will proliferate is an open question. It should be noted, however, that WAN communications have never been a primary bottleneck for DIS. The critical factor has always been, and will almost certainly remain, the rate at which simulation nodes on the local area networks can accept and process PDUs. For this reason, intelligent traffic management - getting the most relevant data to the right nodes and eliminating as much irrelevant ("junk mail") data as possible - is essential to the future expansion of DIS.

5.2.4 Aggregation/Deaggregation

To this point, all interface definitions are concerned fundamentally with the physical state of objects in the synthetic environment (their positions, orientations, electromagnetic emissions, etc.). The tactical state of higher-level, abstract entities (platoons, companies, battalions, etc.) cannot be described simply in terms of the physical objects comprised by that unit. The tactical state of a unit includes such factors as its posture, readiness, intent, objectives, and knowledge of the tactical state of supporting and opposing units. The representation of such higher-level, abstract entities is essential to the effective incorporation of constructive simulations (war games) into DIS. The aggregation of individual platform representations into such abstract entities and the deaggregation of such collective entities into individual platforms are additional challenges to the overall interface definition effort. Aggregation/deaggregation poses a particularly difficult problem for higher-detail simulations where individual objects are detected, tracked, identified, and have real-time interactions with other objects in the scenario.

5.2.5 Correlation of DIS Element Description and Exercise Purpose

A fundamental technical challenge is how to describe the attributes and characteristics of DIS elements (whether live, virtual, or constructive forces) such that the user and exercise control can determine that the elements are appropriate (i. e., valid) for the purposes of the DIS exercise and capable of functioning together acceptably for that purpose. Both an appropriate taxonomy for describing DIS element attributes and characteristics, as they relate to DIS exercise purposes, and a calculus for determining what combinations of DIS element attributes and characteristics are acceptable for specific DIS exercise purposes are needed.

5.2.6 VV&A of DIS Elements and DIS Exercises

Due to limited budget dollars available, models and simulations are being relied upon more heavily and are now being treated as valuable resources. It is now recognized that aggressive VV&A throughout the life-cycle of a simulation is necessary in order to increase the confidence of senior level decision makers in these simulations. As both current programmatic and technical VV&A-related initiatives mature, there will be a growing number of models and simulations which have undergone formal VV&A processes within the Defense community that can be used in DIS exercises.

In addition to many VV&A technical issues, a number of serious programmatic issues exist relative to DIS VV&A, such as who will be the DIS Control, who the VV&A accreditation authority should be, and who should fund DIS VV&A endeavors.

5.2.7 Procurement Outpacing Development

The benefits of DIS technology are catching on. Systems procurement managers either see the need for DIS, or have been required to use DIS, or oftentimes both. Yet because of its immature state, DIS has not always been ready to support their intended usage. The problem is unavoidable, and part of the growing pains of all new technologies. In the meantime, short of full maturity and availability on the part of DIS, we need to continue to advocate its benefits, and wisely and shrewdly build up the infrastructure of DIS (the system of simulators, networks, constructive simulations, and instrumented live ranges) to fully flesh-out the synthetic envi-

ronment so as to make it robust enough to support all DIS users.

5.2.8 Misapplication of DIS Standards

Compliance with DIS standards is sometimes specified in acquisitions where it may not be appropriate, or is sometimes applied without an understanding of what else is required to make the whole system interoperable. One example is a major range instrumentation program. It was required to be DIS compliant, but yet it does not produce basic DIS data (vehicle orientation, articulated parts, etc.) because it does not need it for internal use. Yet if one were to connect a virtual simulation to it, that simulation would need that data to have meaningful interoperation.

5.2.9 Increase Participation by High- Fidelity Simulation Applications

The "I" in DIS is for Interactive. The principal domain for DIS is human-in-the-loop interaction with the simulation and with the synthetic environment. Admittedly, DIS is not appropriate for certain high-fidelity engineering applications, where the questions under consideration include timing and perceptual issues too fine for human perception. Examples would be simulations to study the electromagnetic emission exchanges between a sensor and countermeasure systems—where the pulse characteristics, and the micro-second-duration exchanges are modeled and analyzed. Figure 5-2 illustrates where appropriate DIS usage fits in to today's simulation environment, and where it can fit in the future with growth of the technology.

However, when the time comes to consider the human-in-the-loop ramifications, and to view the system as an organic whole, then the time is right for usage of DIS as an experimental tool. Using DIS coupled with high fidelity simulations is particularly useful in the T&E and systems acquisition arena. The high fidelity simulation community needs to understand this transition.

They need to understand the benefits that DIS can bring to a more complete and accurate understanding of how the candidate high performance weapon and sensor subsystems fit into the total human-in-the-loop system

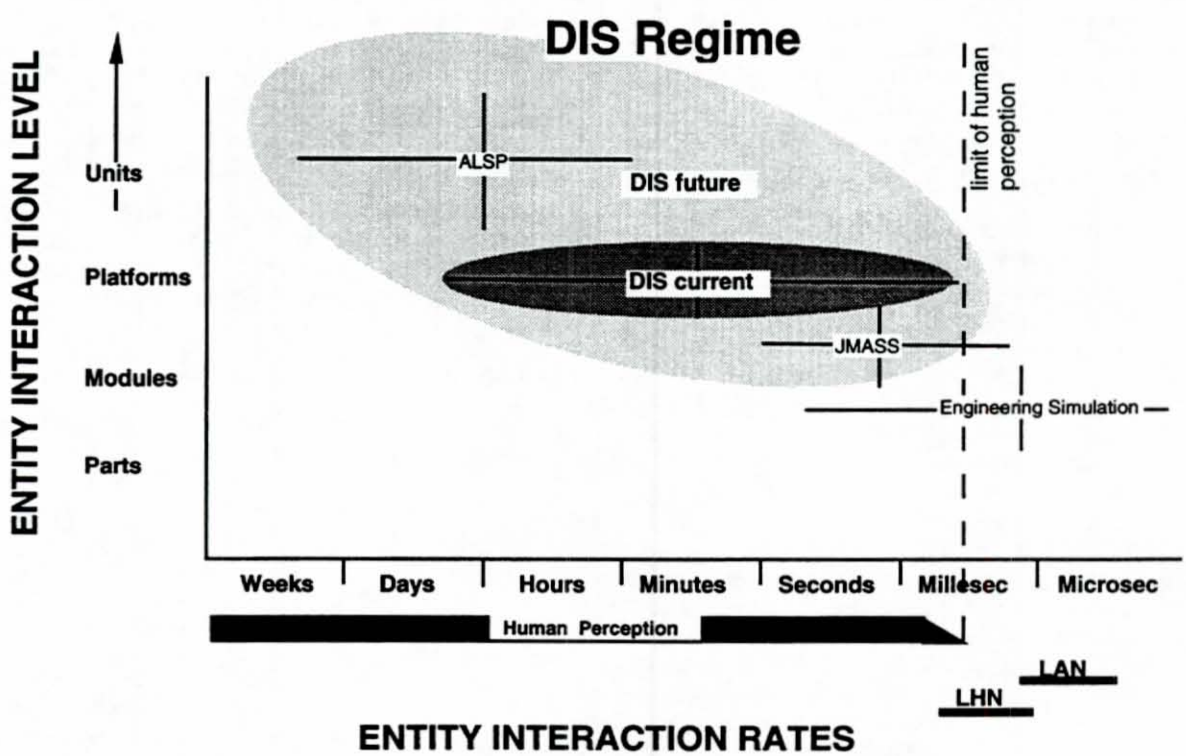

Figure 5-2. Appropriate Regimes of DIS Interaction

and into the force structure as a whole. This usage of DIS may well require different models to test system performance than those models used for high-fidelity component investigations—models that conform to the architecture, protocols, databases, and timing of DIS, yet still retain the key features of the subsystem under investigation.

Models of human performance and behavior will, for the foreseeable future, be poor substitutes for actual human behavior. The key for DIS is this ability to bring the human into the picture.

5.2.10 Role of Constructive Simulations to DIS.

Most large constructive simulations run faster than real time and are at a unit level of resolution rather than platform level. However, these simulations will have an increasing role in the DIS community. These simulations may be run to set the "context", both tactically and geometrically prior to a major exercise. If slowed to 1-to-1 timing and linked to DIS, these simulations can provide a large number of vehicles to the synthetic environment in order to portray the larger context without a corresponding increase in the humans-in-the-loop for control. Constructive simulation can portray the effects of national and long range assets within the high resolution area as well. Lastly, constructive simulation applications can also benefit if scenarios are first gamed with the DIS environment with humans-in-the-loop. There are potential benefits to both the high resolution arena as well as the low resolution war game.

5.3 Military Opportunities

It is important that all this correlation and fidelity work be packaged in a format or process which allows the people who need it the most to use it. These are the DIS exercise users and sponsors, those people who are not likely to make a career out of manipulating DIS environments, but who have specific critical need in a finite time span. It is where the major payoff for DIS technology lies and where the adaptability and affordability of synthetic environments are realized. This is a big challenge, since it is central to whether or not DIS environments are relegated to large, more narrowly focused applications like CCTT or can be applied to the myriad of unique applications that can truly benefit from DIS technology.

The following programs and demonstrations are potential opportunities for the use of distributed interactive simulation and potential development opportunities for DIS.

5.3.1 Advanced Technology Demonstrations

The 1992 Defense Science Board has identified a set of Advanced Technology Demonstrations (ATDs) in support of the ADS thrust. Most of these demonstrations require the use of DIS standards. ARPA is sponsoring the development of two of theses ATDs, the Synthetic Theater of War and Integrated National Guard Training. Other ATDs may be incorporated into existing programs.

5.3.2 Combined Arms Tactical Trainers

The Combined Arms Tactical Trainers (CATTs) are a series of simulators that will ultimately include manned simulators for engineering, air defense, aviation, and artillery - all networked in a DIS environment. The Close Combat Tactical Trainer (CCTT) is the first trainer in the CATT family.

CCTT is a collection of simulators and workstations that will train collective armor and infantry tasks. The simulators and workstations will operate in a common visual battlefield using medium fidelity visual system, fiber optic networks, and distributed interactive simulation. The simulators consist of high fidelity, full crew replications of the M1A1, M1A2, M2A2/M3A2, M113A3, FIST-V and HMMWV vehicles.

Additionally, CCTT will develop a manned simulator that allows the Infantry to fight in the electronic battlefield. Workstations include the Battalion Tactical Operations Center, Field Artillery Tactical Operations Center, After Action Review, Master Control Console, Logistics functions, Engineering functions, and CGF. The CGF will provide the enemy forces for the training exercises.

5.3.3 Tactical Combat Training System

The Tactical Combat Training System (TCTS) will provide an at-sea combat training capability for an entire battle force. This multi-platform training capability is required to maintain aircraft, aircraft carrier (CV), submarine, and surface combatant crew proficiency in Strike Warfare (STW), Anti-Air Warfare (AAW), Anti-Surface Warfare (ASUW), Anti-Submarine Warfare (ASW), Space and Electronic Warfare (SEW), Amphibious Warfare (AMW), and Mine Warfare (MIW) while deployed.

The TCTS will interface with and augment existing combat system capabilities in the areas of tactical training and data collection. The training mission of TCTS is to enhance combat proficiency by providing an on-

board training capability for developing and maintaining combat system and force level team proficiency while operating the on-board tactical combat system suite of equipment.

The data collection mission of TCTS is to provide data collection, transfer, and archiving mechanisms to allow BG staffs, Fleet training commands, and shore-based activities to rapidly access data for evaluation of combat system team proficiency, training exercises, tactics development, and operational readiness.

5.3.4 I/ITSEC Demonstrations

Demonstration of DIS interoperability was provided in the 14th I/ITSEC in San Antonio. Since then, I/ITSEC has continued to support the conduct of DIS demonstrations. These allow the community to try out new PDU concepts and standards.

Participation in these demonstrations gives the potential DIS developer visibility to the Government, provides experience in operating in a DIS environment, and provides feedback to the entire DIS community.

5.3.5 73 EASTING

This program demonstrated the ability to analyze an actual battle, reconstruct the salient details of that battle and then to simulate the battle in a training exercise. This process shows the potential to modify a simulation in order to reflect the current opponent. Future DIS-based applications will seamlessly support this "learning" trait because it is inherently supported in the DIS architecture.

5.3.6 Louisiana Maneuvers

To prepare the Army for World War II, Generals George C. Marshall and Leslie J. McNair instituted a series of General Headquarters-level maneuvers in Louisiana and the Carolinas to assess progress and serve as a laboratory for investigating issues. Today, General Gordon R. Sullivan is defining the Army's vision by using a similar process to lead the Army into the 21st Century. The Louisiana Maneuvers (LAM) of today focuses this vision by:

- Serving as the Army's rallying point in dealing with change.
- Providing a way to intellectualize the transition from a forward deployed Cold War Army to a CONUS-based Force Projection Army.
- Helping to determine what, how much, and when to change policies on issues such as force downsizing, upgrading doctrine, reassessing force design and material requirements, improving training and readiness, and emphasizing leader development.
- Demonstrating the thrust areas of the Army's current capabilities by exploiting technology in simulations, communications, and analysis; and assessing and demonstrating capabilities to execute warfighting responsibilities.

As the Army's senior leadership identifies specific policy and warfighting issues, LAM will be employed as an evaluation vehicle to study the issue and to assess new ideals and options in "real-time". Evaluations will be conducted using constructive simulations, virtual simulations and live environments, often interoperating with these resources through DIS. The exploration of simulation and modeling and the application of DIS technologies are key components of the LAM process.

5.3.7 Constructive Simulation Linkage Projects

The synthetic environment of DIS is envisioned to provide seamless interoperation of virtual, live and constructive simulations. Constructive simulations, to include computer generated forces, will add depth and breadth to the virtual battlefield. The following subparagraphs describe on-going projects that involve the linking of constructive simulations to the DIS world.

BBS/SIMNET. The Brigade/Battalion Simulation (BBS) is a distributed command post exercise (CPX) driver and command staff trainer. The Naval Research and Development Laboratory (NRaD) and the Army are sponsoring a project to link BBS with SIMNET. Limited linkage was recently demonstrated at the Schweinfurt SIMNET facility. BBS brings Command and Control aspects to the SIMNET arena.

Janus/DIS. This is a brigade/battalion level simulation whose resolution is at the item/system level. Janus is used by TRADOC Centers and Schools for analysis work and it is also used for training applications. As an integral part of the Armor/Anti-Armor Advanced Technical Demonstration (A2ATD), the Janus model will have a DIS interface.

Eagle/SIMNET. Eagle is a Corps/Division level aggregated simulation. At the May '93 AUSA conference, an Eagle link to SIMNET was successfully demonstrated. This project establishes a software link that allows the aggregated units in Eagle to be transported into the SIMNET virtual world on demand. Aggregate support units in Eagle are also able to af-

fect the battle within the virtual world (e.g. artillery support can be requested by a simulator or controller in SIMNET and the resulting fires from an aggregated artillery unit in Eagle will impact within the virtual world). The project is currently switching to DIS protocols.

Battlefield Distributed Simulation Developmental (BDS-D). This program is the Army's networked simulation testbed serving to evaluate new design concepts with the warfighter-in- the-loop. The project will make tools available to simulate before and during building, testing, buying and fielding new weapon systems. It will also be used to develop and test new tactics and doctrine. The purpose of the BDS-D ATD is to demonstrate an accredited warfighter-in-the-loop, battalion level combined arms synthetic environment that will support virtual prototyping, concept formulation, requirements definition, effectiveness evaluation, and mission area analyses.

5.3.8 Insertion of Individuals into the Virtual Environment

Significant work is getting underway to provide mechanisms that will allow individuals to become part of a virtual environment. Applications for this approach include the 1) testing of systems carried and used by individuals (communications equipment, armor, etc.) in complex and stress inducing environments and 2) the injection of complex individual behavior into a virtual exercise. Significant work is being done in this area by the following two projects.

Integrated Unit Simulation System (IUSS) is an object oriented very high resolution simulation of dismounted soldier/ battlefield environment interaction. Its resolution is from individual soldier to company level groupings of soldiers. IUSS is used to study the effects that changes in individual soldier's equipment, conditioning, and capabilities have on the accomplishment of small unit missions. IUSS provides the ability to perform real time analysis of soldier/unit/equipment performance both during and after simulation execution using commercially available software. The Dismounted Battle Space Battle Laboratory has recently sponsored addition of DIS compatibility to IUSS.

Individual Portal (I-PORT) inserts an individual into a virtual exercise by applying sensors to the human body that can determine direction, velocity, and orientation of that body, converts the information to DIS-like PDUs, and transmits them. The virtual world is presented to the individual via a head mounted display or projected displays on surrounding screens. Several prototypes of this system were demonstrated at the Dismounted Battle Space Battle Laboratory at Fort Benning in February 1994.

This work is being done in support of the 21st Century Land Warrior initiative.

5.4 DIS Beyond DoD Applications

One can imagine applications for DIS which could, at some time in the future, exceed in number those currently envisioned for military applications. The future of non-DoD applications will come from the fact that DIS has established ***standards*** by which simulation machines can communicate. These standards will be a breeding ground for future application development which leverages new technology and systems from the current DIS work. For example, those vendors who currently sell Global Positioning System (GPS) receivers to the general public for as little as $300 are able to do so because of the DoD investment in military receivers costing tens of thousands. Anyone can build such equipment since the GPS standard is well known and open. This spawns competition which results in better products at lower prices. Future situation displays will be available at affordable prices as a result of today's investment in "magic carpet" displays which understand a *standard language* - DIS. Future field instrumentation packages and field instrumentation communication systems will be available to the commercial world at a substantially reduced price due to the ongoing work in DoD sponsored field instrumentation.

5.4.1 Air Traffic Control/Planning

Ten to twenty years from now all commercial and general aviation aircraft may be equipped with GPS receivers and DIS compatible field instrumentation packages. These aircraft may broadcast their "entity state" to all other aircraft and to ground controllers. Collision avoidance algorithms may be integrated with the dead reckoning algorithms which have been developed for DIS and pilots can be warned far in advance of any potential close contacts. Automatic methods which take into account the time motion of both aircraft can insure that the actions taken by one aircraft do not negate those taken by the other. Situation displays in each aircraft and on the ground can allow each pilot and controller to see the others. Navigation may be vastly improved and air travel made safer through the use of standardized terrain databases that can accurately depict the aircraft's po-

sition relative to the terrain in all weather conditions. Mountain flying in particular can be much safer.

Meanwhile on the ground, the FAA is considering modifying the labyrinth of airways due to changing air travel demographics. Entity state PDUs from actual aircraft can be fed into a networked system of computer simulations which analyze the effect of various changes to the current air traffic system. A mixture of real and simulated entities can provide realism as well as controlled variables for the simulation and analysis.

The FAA, in conjunction with several airlines, recently ran trials in Automatic Dependent Surveillance where aircraft flying over the North Pacific broadcast their GPS position to ground based ATC components.

In addition, the FAA's NSC program is using distributed simulation techniques to link ATC simulations through a common mechanism to provide a better system development process in which the systemic effects of National Airspace System (NAS) enhancements, including new systems, technologies, and procedures, can be studied either individually or collectively.

One can carry this line of thinking to any situation where things move around and it is important to know their positions. This is true of ground vehicles and/or ships at sea. Traffic analysis and planning, congestion control, and collision avoidance are but a few of the future applications of DIS.

5.4.2 Disaster Response Training

Hurricanes, floods, earthquakes, riots, and large fires represent situations for which public safety agencies are ill prepared. Staged disasters and drills are helpful but cannot prepare an organization for the chaos that comes with a real disaster. Historically the major problems are in the areas of command and control and coordination of the responding personnel. DIS based simulations have the potential to train and test large numbers of personnel in realistic situations by integrating constructive simulations, crewed platform simulations, and live crews doing "drill" responses. It may not be feasible to assemble a group of public safety personnel in one city large enough to make the simulation realistic, but a DIS based simulation could assemble personnel from anywhere in the country.

5.4.3 Marketing

It's the year 2010 and you have decided to buy a new car. You go into your living room, sit down in your favorite easy chair and put on your VR goggles and gloves. You select the car shopping option from one of thousands of home shopping categories and then proceed to the selection section. You are interested in a sports car which cost less than a certain amount. You are presented with five candidates which meet your criteria. One by one you enter the cars, sit down, and take test drives. You particularly like to take vacations in the mountains so you select the Blue Ridge Parkway from thousands of possible places to visit. Off you go, accelerating, braking, as you speed through the course, enjoying the scenery and experiencing each car.

All of this possible because DIS has developed standards for interactive simulation which have been adopted by the thousands of vendors which now supply software objects, data bases, video scenery, image generators, etc. to an ever growing interactive television industry. It has totally changed the way people shop, get their news, and enjoy their leisure.

5.4.4 Recreation

The increasing fidelity of platform simulators, their decreasing price, the availability of low-cost high-bandwidth communications, and the adoption of DIS standards will bring interactive simulation into the home of anyone who wants it. The fidelity of the simulation will be better than anything available today. In particular, the visual scenes will be indistinguishable from reality.

One such application might be America's Cup yacht racing. Your simulator could represent a particular boat and it would respond precisely the same way its prototype would in the same wind and sea conditions. You may have tweaked the design to get a half knot greater speed under certain wind conditions. You may join a race already underway on the network, or you may participate every Saturday afternoon with the same opponents, no matter where they are located.

Another possible application is the reenactment of historic battles such as that pioneered by the 73 EASTING project. History buffs and aviation enthusiasts will be able to restage and refight the great air battles over Europe during World War II.

SECTION 6

CRITICAL ISSUES

This is an in-depth discussion of those issues deemed critical to long term success of DIS. Discussion includes impact on DIS if the issues are not dealt with successfully, what resources will be needed (supporting infrastructure, technology breakthroughs, etc.), and basic recommendations for dealing with the issues.

6.1 Incomplete Architecture Definition

A well defined systems architecture is essential to provide a framework for the application of DIS concepts. The various standards currently being developed through the DIS Workshop will allow users to specify interoperable systems for specific applications. However, without a comprehensive systems architecture definition, there is no guidance to insure that independent developers would apply the standards in a consistent manner. Architectural consistency is needed, therefore, to support future programs in which independently developed DIS-based applications may be integrated to create larger-scale synthetic environments.

6.1.1 Basic Architecture Requirements

Physical and operational architectures need to be developed and correlated. The physical architecture must define major system components, the functions of each component, and the interfaces between components. In addition to supporting design consistency, these definitions must be comprehensive enough to bound the scope of applications supported by the architecture. For example, the application of DIS is currently being limited to real-time systems. This limitation should be clearly articulated in the architecture definitions.

It is also desirable to develop operational architectures which describe the various real world environments which DIS synthetic environments are intended to replicate. The operational architectures will provide a reference to support the process of defining the necessary physical system components and interfaces. The operational architecture will also provide a basis to assess how well the physical architecture can replicate various real world environments. This capability will support users in determining DIS applicability. It will also support DIS Workshop leaders in defining desired architecture enhancements and prioritizing future standards development to facilitate those enhancements.

6.1.2 Development Approach

The first steps in addressing this critical issue are to develop some strawman operational architectures and to document a baseline physical architecture based on today's DIS concepts and standards supported capabilities. The physical architecture should be defined at several levels of detail. At the highest level a Technical Reference Model should be provided. Lower level descriptions should then be developed providing successively more detail on system components, component functions, and component interfaces. At the lowest level documentation should be provided to describe how the architecture supports specific DIS interactions such as entity interactions, emissions, radio communications, time management, and simulation management. The physical architecture definitions should provide standardized terminology, using existing, accepted terms when possible. An open architecture should be defined which does not dictate the use of specific current technologies. The architecture should also not restrict innovative implementation techniques.

Once a baseline physical architecture is defined, a process should be instituted to develop and refine additional operational architectures, assess the physical architecture for deficiencies and application issues, provide recommendations for future architecture changes and provide architectural modifications.

An example of a typical issue would be the desire to allow DIS-based applications for non-real-time systems. Another example might be the desire to use common networks to handle both real-time operations and support functions such as database updates.

The following is an outline of recommendations:

- *Organize a forum to define and document baseline system architectures (expanding on ADST strawman architecture)*
- *Solicit Workshop acceptance of baseline*
- *Organize a forum to pursue growth and refinement of system architectures including the creation and management of processes to:*

  identify and assess deficiencies and issues

  define and assess alternate solutions

provide recommendations to modify architecture and supporting standards

- *Monitor DIS-based applications for feedback on applicability and completeness of architecture*

6.2 Lack of Maturity of Standards

The benefits achievable from the application of DIS concepts have been clearly recognized by the DoD as well as by many non-military potential users. Based on this recognition, the government is rapidly developing initiatives and incentives to utilize DIS to enhance the functional processes of: analysis, acquisition, testing and evaluation, training and education, and logistics and production. As a result many users are anxious to pursue DIS projects. The issue of concern, however, is that users have been provided with little information on the levels of application achievable with the current standards and supporting technologies. To complicate the situation, there have been numerous highly publicized demonstrations which have verified the applicability of DIS but at the same time have created the risk of generating user perceptions that DIS is fully mature.

6.2.1 Guidance for the Application of Standards

To address the issue of overselling DIS, the DIS Workshops must initiate an active program to educate potential users on DIS concepts and current capabilities. In addition, users must be provided with guidance on how to apply DIS concepts and how to specify DIS requirements. This guidance is necessary since the emerging standards provide a tremendous amount of versatility to support the diverse spectrum of applications anticipated. Also, guidelines are required to assist users in making design decisions in instances when alternate supporting technologies are available.

Educating users addresses the immediate issues of understanding current capabilities and understanding how to apply those capabilities. However, the lack of maturity of the standards should be clearly recognized as the underlying issue. Addressing this issue in a formal, well managed and expedient manner is a major challenge facing the DIS Workshops. In addition, it is necessary to promote testing of the emerging standards.

6.2.2 Recommended Approach

The following is an outline of recommendations:

- *Pursue issuance of a government contract or organization of a DIS Working Group of technical writers to develop:*

  Training programs for users

    Capabilities of DIS

    How to apply DIS (basics and options)

  Guidance documents to support training

  Publications on status of DIS

    Current capabilities

    Capabilities in development

- *Continue to aggressively pursue development of standards*

  Monitor desired user applications

  Develop operational architectures to represent applications

  Use architecture analysis to help prioritize standard development tasks

- *Continue to promote standards testing*

  Work closely with STRICOM/IST DIS Testbed Program

  Monitor DIS-based applications

  Employ expertise of applicable Subgroups to identify and address associated DIS unique issues.

6.3 Lack of Correlation of Environments and Entity Models

Interoperability is the heart of DIS. It is interoperability that allows distributed simulations to be interactive. To create interoperability, two general requirements must be addressed. First, an agreed upon communications mechanism must be implemented to allow simulations to dynamically interchange entity and event information during integrated exercises. The second requirement is that the simulations must operate in a common synthetic environment. When the participating simulations are distributed, with each providing its own localized representation of the environment, there is a need for correlation between the individually generated environments. The facets of environment for which correlation must be addressed are innumerable. Included are natural components such as terrain, vegetation, ocean bottom, weather, clouds, time-of-day, sea-states, etc. and synthetic components such as cultural

features, bomb craters, weapons, chaff, flares, etc. In addition, participant simulations and automated forces are entities which represent components of the environment as perceived by other participants.

To address the issue of correlating the development and application of models, we must first define all the model subcomponents which affect interoperability (i.e., a radar subsystem, a sea-state algorithm, terrain cultural features, etc.). Methods must then be developed to provide quantifiable measures for these subcomponents in terms such as fidelity, realism and validity.[12] Finally, criteria must be developed to determine the degree of subcomponent correlation that is required to support the mission task performance and workloads associated with specific DIS-based applications. The degree of correlation in each case would be defined by the desired fidelity, realism, and validity level and the acceptable deviations to each level.

In addition to addressing the issue of correlating the development and application of environmental and entity models, we must also consider correlating the representation of those environments to the individual participants. In particular, we must address the visual and sensor systems which provide a primary simulation interface between crews and their environment. The source of this issue relates to the fact that the technologies that support simulation visualization, while progressing rapidly in recent years, are still immature relative to their ability to replicate, in detail, the complex nature of real world environments. In addition, there are technical limitations on current capabilities to collect, store and process detailed environmental data. Finally, it should be noted that the visualization techniques that are currently available are generally a major simulation cost driver. These factors drive us currently to assess each procurement individually and to select key visualization capabilities based on performance and cost tradeoffs.

Obviously, different user applications will lead to different trade-off selections in virtually every aspect of the environmental representation from entity fidelity to terrain database content and special effects detail. In addition, different visualization techniques may often provide different optimizations. Clearly today, the probability of finding full environmental correlation between two independently procured simulations is approximately zero. In the past, this was considered a manageable limitation since users were only required to tailor each system for a specific and generally stand-alone operational requirement. With the current emphasis on exploiting the benefits of DIS concepts; however, a device procured today for a specific application such as crew training should be also capable of supporting future research, acquisition or force readiness studies.

Obtaining environmental correlation may be the most complex challenge facing the DIS community. Project 2851, the DIS Workshop, and numerous researchers are currently attempting to address pieces of the correlation puzzle. Due to the importance of correlation to the advancement of DIS however, it is highly recommended that steps be taken to significantly expand the modeling and simulation emphasis and funding required for associated analysis, research and development activities. It is also recommended that the issue be treated systematically perhaps through a program or agency that studies correlation as a total issue while providing oversight and coordination between working groups and researchers addressing individual elements of the issue. We must strive for a better understanding of environmental correlation and from that understanding seek to evolve cost effective concepts, architectures and supporting technologies which will allow the implementation of large-scale correlated synthetic environments.

The following is an outline of recommendations:

- *Solicit and encourage correlation studies, development and standards activities to:*

  Systematically analyze correlation in the total DIS context

  Fully define modeling subcomponents that affect correlation

  Study and quantify task/mission performance and other impacts of correlation deviations

  Study factors that constrain correlation

  Develop methods to define and quantify correlation measures

  Study and develop methods to provide common techniques and/or standards for creating models and associated databases

  Develop methods to test correlation

  Develop methods to feedback corrections to minimize correlation errors (e.g., in terrain databases)

  Research methods to compensate for correlation differences (e.g., image enhancements)

Study utilization of environmental servers and correlation support systems (e.g., a line-of-sight server)

Study and develop techniques to support dynamic elements of the environment

Develop common technologies to create, store, and process models and associated databases

- *Increase emphasis on and support of a consortium of experts to address correlation at the system and element levels*
- *Solicit increased government support*

  Support of consortiums and research activities

  Development of sets of correlated databases
- *Pursue issuance of a government contract or organize a DIS Workshop group to develop documentation on correlation issues and/or guidelines for users to understand correlation considerations and trade-offs relative to generating procurement specifications.*

6.4 Lack of Supporting Technologies

The opportunities for applications of DIS concepts appear endless. However, the scope of those applications will always be bounded by technology limitations. The technologies of interest may be organized into several domains. These domains and their relationship to the DIS infrastructure are examined below. Some of the following discussion is based on similar discussions in the DoD Synthetic Environments (SE) Strategic Plan.

Better Representation of the Physical Environment. This has been both the driving force and the goal of image generator and display system developers. The development of these technologies has been very rapid. Much of it has been fueled by intense competition between the major companies in this arena. The drive to make the representation of the environment ever more realistic, more efficient, and less costly has led the developers down different technical approaches. These different approaches, in turn, have led to differences in representations of the same virtual world that somehow must be correlated in a DIS environment. Despite the technical progress made in the area of environment representation much more is needed to fulfill the requirements of DIS-based applications. Such progress must be coupled with efforts to correlate the representations from different sources.

Human Characteristics and the Environment. This domain includes behavior and capabilities of individuals and groups. Major subareas include: human databases, human models, and simulation participant characteristics. Progress is needed in high-resolution physical measurements, digitizing of human factors data, and development of behavior and cognition databases. Research is needed in perception, sensory interactions, group behavior, and fidelity requirements. Definition of the technologies for computer generated forces is a critical near-term need.

Interface Factors. This domain deals with linking participants with all necessary aspects of the synthetic environment. Major subareas are the relationship of behavior models to synthetic environments, modeling the stresses of sustained operations, human computer transaction modeling, high data transmission rates for advanced sensor-system interfaces, and multi-sensory environments. Research is needed in flexible user-interface stations, helmet-mounted displays, large screens, liquid crystal displays, and systems for joint angle measurement, tactile stimulation, and force feedback. Human performance assessments will require the synthetic environment to have capabilities to preserve data for post processing.

Computation and Communications. This domain includes technologies for software applications, data storage and retrieval, and computer and network infrastructure. The technologies of this domain can be grouped into six subareas: high-performance computer systems, high-performance networks, assured computing, advanced software methods, distributed operating systems, and prototyping and specification tools. Although the federal government is already driving the development of hardware and software for high-performance computer systems such as massively parallel processors, extra effort will be needed for synthetic environments.

Recent progress in advanced software methods, such as AI, apply to robotics, advanced decision aids, training, and mission rehearsal, but progress is still required. Critical issues focus on the human-in-the-loop and the integration of computer science and cognitive engineering. Distributed operating systems require advances in networking and multi-level security.

The Synthetic Environments Strategic Plan also provides strategies to achieve the technical maturity necessary to support complex, integrated synthetic environ-

ments. The plan is a good indication of federal government's intentions to pursue DIS related technology advancements.

To keep the DIS community informed on technology issues and advancements, we recommend the organization of a DIS Technology Advisory Group. This group would perform the following functions:

- *Monitor and evaluate current technologies relative to their impact on DIS-based applications (i.e., as related to operational architectures discussed in Section 6.1)*
- *Monitor R&D activities to determine projections or availability of technology advancements*
- *Advise key government agencies on DIS application constraints and potential impacts to progress*
- *Develop guidance documents (and updates) for users describing available technologies, associated constraints in DIS-based applications and projections of enhanced capabilities*

6.5 Lack of Demonstrated VV&A

Informal verification has been performed on DIS PDUs for various network activities such as the WAR BREAKER Systems Engineering and Evaluation program. Effective validation has yet to be demonstrated for DIS exercises, which is a fundamental requirement for accreditation. There are several OSD and service-sponsored projects which are creating networks which may be used to help develop an effective VV&A process. It is anticipated that DIS exercises will require an unprecedented level of coordination and cooperation to obtain adequate data from live testing to ensure multiple models accurately represent integrated systems performance. For a number of DIS exercise circumstances, partial VV&A may be possible without heroic levels of cooperation.

We continue to need basic VV&A theory developed so that we can make more orderly progress in this regard -- such as, how far a partial VV&A can legitimately carry an exercise. The following items are recommended:

- *The VV&A Subgroup should seek to identify and address the technical issues related to DIS VV&A, developing recommended technical approaches to resolve these issues.*
- *The VV&A Subgroup should identify voids in DIS VV&A-related research.*
- *Leadership of the VV&A Subgroup should stay closely coupled with the other VV&A endeavors within the Defense community.*
- *The VV&A Subgroup should develop draft VV&A-related portions for the DIS exercise control standard.*

SECTION 7

GOALS AND OBJECTIVES

This section sets out a comprehensive set of general goals and supporting objectives to guide the development of the DIS infrastructure for the foreseeable future. These goals and objectives cover both the development of standards, over which the DIS community has direct control, and supporting technical developments, which the DIS community can only anticipate and perhaps influence.

The goals are described and explained in the following sections. They are repeated in Table 7-1 along with measurable objectives that can be used to determine progress in meeting these goals at two and five year intervals. For some goals the table also includes objectives that will only be achieved some time after the five year point.

These goals were defined by representatives of the technical working groups. Many of the goals are related to information presented elsewhere in this document, but there is no intent to align them with other sections of the document.

7.1 Interfaces

7.1.1 Increase Functional Areas Covered by PDUs

The DIS community needs to plan for the expansion of numbers and type of PDUs due to changes in military doctrine and application, and expansion of DIS into non-DoD applications. Categories of military applications include test and evaluation, training and mission rehearsal, and research and development. Non-military applications include civil aviation command and control, entertainment, disaster relief, and coordinated team training.

7.1.2 Balance PDU Information Content and Bandwidth Efficiency

As the number of entities participating in a DIS exercise continues to grow, bandwidth availability and cost will be major issues. In order to minimize the cost to the participants, DIS will utilize bandwidth conservation efforts to the extent feasible. The following conservation methods will be employed:

More Efficient Dead Reckoning. Different algorithms will be employed for different entity types based on the characteristics of their movement. The general goal is to reduce the number of entity state updates that must be conveyed.

Streamlined PDUs. Remove static and infrequently changing information from high frequency PDUs (e.g. entity state), send only dynamic data that has changed since last sent, and represent data as compactly as feasible. In situations where bandwidth is very limited, use PDU sets that have been optimized for bandwidth efficiency and accept possible lack of data. If feasible, define a tailorable set of such PDUs.

7.1.3 Include Real and Constructive Simulations

It is desirable to expand entity interactions beyond the virtual-to-virtual interface to encompass live-to-live, live-to-virtual, live-to-constructive and virtual-to-constructive interfaces. Constructive-to-constructive interfaces are currently being addressed under the Aggregate Level Simulation Protocol (ALSP) program. A logical extension of this effort is to develop an ALSP/DIS interface.

The available bandwidth for live systems, which exchange data via RF links, is significantly less than for virtual or constructive simulations which utilize terrestrial wide area networks to exchange data. In order to interface live entities to virtual and/or constructive entities within the synthetic environment, future standards will define shortened or "express" PDUs to exchange data more efficiently.

7.1.4 Force Aggregation/Deaggregation

The aggregation of multiple entities into a single entity for the purpose of interaction is desirable. Aggregation is generally applied to unit models in which some or all platforms and vehicles are treated as organizations of platforms (e.g. flights, convoys, squads) and are not individually distinguished. In addition to organization (entity) aggregation, models can aggregate time (using large time steps such as minutes between simulation updates), space (gross resolution in sectors, hexes, boxes, etc. representing square kilometers rather than square meters), and functions (unit rather than platform level attrition, maintenance, etc.).

Interim steps to reaching this goal include:

- Identifying user-defined aggregation requirements.
- Conducting Advanced Technology Demonstrations involving a mix of aggregated and single platform simulations in the same synthetic environment.
- Conducting a cost/benefit study of which schemes provide the most benefit in terms of reduced network bandwidth or cost in terms of increased processing power requirements.
- Incorporating aggregation/deaggregation schemes into the DIS family of standards which provide the highest degree of functionality and the lowest cost/benefit ratio.

7.2 Communication

7.2.1 Very Large Number of Entities

It is critical that the design of the DIS architecture and protocols be flexible enough to support increasingly large numbers of entities interacting within the synthetic environment. ARPA presently estimates the need for exercises with 100,000 entities. These entities will be a mix of live, constructive and virtual simulations. The search for the most efficient communication schemes is a critical part of the development of DIS standards. Several "scalability" studies are under way to examine this basic issue. The findings of these studies will guide developments in these areas.

7.2.2 Communication Profiles

The approach to providing communication architecture specifications for the DIS environment has been to begin by specifying available protocols in an internet based profile including UDP and TCP/IP. The original intent was to migrate the profile to that of a GOSIP compliant profile.

In recent years, the types of applications requiring DIS support has grown enormously. No longer will a single communications profile provide the needed services for all DIS applications. The goal is to develop a set of profiles from which the DIS implementer's can choose the most appropriate profile for their application.

7.3 Security

7.3.1 Security Guidelines and Rules

The DIS standards will provide intersite and intrasite interoperability between DIS participants. DIS standards neither provide nor preclude specific security requirements. Each DIS exercise administrator has the freedom and responsibility to make security relevant decisions appropriate to the circumstances. To assist him guidelines in the following areas will be provided:

- Examine the choice of network to be used for the exercise.
- Examine the type of network configuration (e.g. definitions of host addresses, types of service, definition of multicast groups).
- Examine sensitivity level of exercise and its participants.
- Examine choice of security operating mode (e.g. system high, multilevel ...).
- Examine security policy (audit requirements, access controls)
- Examine protection mechanisms against threats.

7.3.2 System/Site Security Accreditation

The DIS community will establish an accreditation guide based on the security guidelines listed above. The accreditation guide will provide detailed alternatives for each guideline and the implications of using or not using an alternative.

7.3.3 E3 Encryption Bottleneck

Present end-to-end encryption (E3) systems are imposing severe limits on the amount of data that can be put through them. The goal is to minimize the impact of these constraints by improving the performance of E3 systems or finding alternatives to them that provide adequate levels of protection, but with greater throughput.

7.4 Environment

7.4.1 Dynamic Terrain

In the real world, terrain is constantly changing due to the efforts of builders (e.g. roads, bridges), warriors (e.g. destroyed bridges, craters) and sometimes nature (e.g. snow covering). The synthetic world must reflect these changes. DIS standards will include mechanisms to support dynamic terrain.

7.4.2 Atmospheric Effects

In the real world the effects of nature have major influences on the battlefield. DIS standards will include modeling of atmospheric effects (e.g. smoke, clouds, wind drift, and ambient light).

7.4.3 Underwater Phenomena

DIS standards will include modeling of underwater phenomena such as natural and artificial sound sources, and the propagation of sound. The propagation of sound will be effected by parameters like salinity, range, temperature, and pressure.

7.4.4 Improve Database Correlation

The DIS community will improve database correlation to the point that variability of results due to different entity actions is greater than variability of results due to differences in representation of the environment.

7.5 Management

7.5.1 Identify Mechanisms to Plan, Initialize, Control, and Debrief Exercises

Pre-exercise activity, control of the exercise while it is in progress, and debrief mechanisms that permit the evaluation of an exercise are essential to any significant simulation effort. These are also the most difficult. DIS standards in this area will go far in making these tasks easier, and in making the results of them more usable.

7.5.2 Identify Mechanisms to Implement Security Requirements

The distribution and control of encryption keys and other tasks involved in the management of security have traditionally been time-consuming and difficult. Some well established procedures that are DIS-wide will go far in making these task more efficient and less resource consuming.

7.5.3 Implement Network Management System

DIS networks will be put together in a variety of ways, both physically and logically. The manager of the network, whatever its shape or size, will be faced with a myriad of tasks such as address assignment, bandwidth allocation, security levels, connectivity, performance monitoring, and the like. Tools and processes tailored to the DIS environment will make the tasks of all DIS network manager easier.

7.6 Implement Effective VV&A Processes for DIS Exercises

Simulation has little value unless the model(s) on which it is based can be shown to reflect the real world with fidelity adequate for the purpose of the simulation. The VV&A processes on which such determinations are made vary widely between the military services and organizations within the services. The DIS standards community has an opportunity to integrate these processes into a common set that will serve the entire modeling and simulation community.

7.7 Develop Measures of Performance and Effectiveness

The primary purpose of a DIS exercise is to determine the performance of individuals or systems under the conditions simulated in the DIS virtual environment. Consequently, it is very important that DIS include tools to simplify the job of the exercise evaluator. The DIS community is developing robust performance measurement capabilities at two levels. Measures of Performance quantify how the system/individual performs its functions in a given environment (e.g. reaction time, number of targets nominated, task completion time). The DIS community has developed special PDUs for capturing this information. Measures of Effectiveness indicate how well the system/individual meets mission goals and can be directly observed and calculated from Measures of Performance, or derived from evaluator judgment. The DIS community has developed special functions and displays for helping the evaluator derive Measures of Effectiveness from the Measures of Performance data.

7.8 Ensure Interoperability of Computer Generated Forces (CGF)

CGF mechanisms will play key roles in DIS simulations by providing opposing forces, supporting forces, and forces needed to permit a small number of humans to represent a much larger force. CGF is in relatively early stages of development and much work needs to be done to permit them to play roles that appear realistic to humans in the synthetic environment.

Table 7-1 DIS Goals and Objectives

Goal	Two Years	Five Years	Out Years
Increase Functional Areas Covered by PDUs	ITMC PDU 2.0 accepted by IEEE. Working draft of ITMC PDU 3.0 available	ITMC PDU 3.0 & 4.0 accepted by IEEE. Subsequent version(s) available in draft form. Initial PDU set for non-military users defined	Continued refinement of military PDUs. Substantial development of non-military PDUs.
Balance Information Content & Bandwidth Efficiency of PDUs	Draft set of express PDUs accepted by DIS Steering Committee (S.C.) More efficient dead reckoning algorithms defined, tested, and accepted.	Express PDU set incorporated into PDU Std & in widespread use in field instrumentation (FI) exercises	
Expand Interfaces to Include Live & Constructive Simulation	ALSP/DIS interface mechanism defined. Draft set of FI PDUs accepted by DIS S.C. Advocate use of native DIS mechanisms for WARSIM 2000	WARSIM 2000 (DIS-based) Operational. FI PDUs in common use in live exercises	
Support Aggregation & Deaggregation of Forces	DIS PDU representation of aggregated forces defined. Mix of aggregated & single platform simulations in same exercise demonstrated.	Mix of aggregated & single platform simulations part of Synthetic Theater of War (STOW) Demo	Single platform & multilevel aggregation of forces in seamless unified integration
Support Very Large Number of Entities (ARPA estimate = 100,000)	Requirements & standards for scalability mechanisms (e.g. multicast addressing) defined	Scalability mechanisms in wide use. WAN infrastructure in place (e.g. routers, gateways) to use T3 (45 Mbits/sec) capabilities.	Improved scalability mechanisms (e.g. intelligent gateways) in wide use.
Transition to GOSIP Protocol Suites	OSI multicast protocols standardized. GOSIP (or successor) protocol suites defined.	GOSIP (or successor) protocols capable of supporting DIS requirements available on experimental basis.	DIS regular use of international standards for real time communications.
Security Guidelines & Rules to Protect DIS Data	Draft document of guidelines & rules accepted by DIS S.C.	Guidelines & rules adopted by DIS related accrediting agencies.	

Goal	Two Years	Five Years	Out Years
Establish Process for DIS System/Site Security Accreditation	Draft document of process accepted by DIS S.C.	Process accepted by accrediting agencies. Process in wide use by users seeking accreditation.	
Advocate and Support Removal of E3 Encryption Communication Bottleneck	E3 devices with bi-directional T1 (1.5 Mbits/sec) available. Standardized mechanism for parallel E3 devices established. Alternatives to E3 approach defined.	E3 devices with bi-directional T3 (45 Mbits/sec) available.	E3 devices available to support 100,000 entity exercises.
Support Dynamic Terrain	Mechanism & standards to represent terrain changes defined & accepted by DIS S.C.	Dynamic terrain implemented on limited basis.	Dynamic terrain universally supported.
Support Atmospheric Effects	Mechanism & standards to represent atmospheric effects defined & accepted by DIS S.C.	Atmospheric effects implemented on limited basis.	Atmospheric effects universally supported.
Support Underwater Phenomena	Mechanism & standards to represent underwater phenomena defined & accepted by DIS S.C.	Underwater phenomena implemented on limited basis.	Underwater phenomena universally supported.
Improve Database Correlation	Dependable, accurate measures of correlation defined & validated. Correlation index established & accepted by DIS S.C.	Providers of DIS environment databases accept measures & index as standard. Database correlation problems minor & rare.	
Identify mechanisms to plan, initialize, control, and debrief exercises	Baseline functionality & standards for exercise management accepted by IEEE Existing mechanisms (e.g. Internet MBONE SD package) evaluated for adaptation & use.	Robust & comprehensive exercise management package widely available.	
Identify mechanisms to implement security requirements	Baseline functionality & standards for security management defined & accepted by DIS S.C.	Robust & comprehensive security management package widely available.	

Goal	Two Years	Five Years	Out Years
Implement Network Management System	Baseline network management functionality & standards, unique to DIS, defined & accepted by DIS S.C.	Robust, comprehensive, and DIS oriented network management package widely available.	
Implement Effective VV&A Processes for DIS Exercises	Baseline programmatics for DIS VV&A process accepted by DIS S.C. Draft taxonomy of Fidelity Descriptors (FD) and Characteristics accepted by DIS SC.	Basic VV&A & FD taxonomy and initial parts of a calculus for describing characteristics and attributes of DIS elements and their relationship to DIS exercise objectives accepted by IEEE	Full development & wide acceptance of the taxonomy & calculus, tools to support VV&A process available. FD taxonomy implemented in database format with available DIS-based applications cataloged therein.
Develop Exercise Feedback Mechanism	Baseline functionality & standards for exercise feedback (including battle space visualization) defined & accepted by DIS S.C.	Robust, sophisticated, battle space visualization, analysis, & review package widely available.	Robust, sophisticated, battle space visualization, analysis, & review package in universal use.
Develop Measures of Performance	Core set of measures of performance defined, validated, & accepted by DIS S.C.	Full set of measures of performance defined, validated, and in wide use.	
Develop Measures of Effectiveness	Core set of measures of effectiveness defined & accepted by DIS S.C.	Core set of measures of effectiveness validated by DIS S.C.	Full set of measures of effectiveness in wide use.
Ensure Interoperability of Computer Generated Forces (CGF) Individual Platform Entities	Parameters defined governing low level behavior (e.g. moving & shooting). Tests defined for CGF detection capabilities.	Means developed for correlation of low level unit behavior. Tests developed for correlation of higher level behavior of individual platforms.	Interoperable platform behavior assured.
Ensure Interoperability of Computer Generated Forces (CGF) Aggregated Entities	Key behaviors to be represented defined. Parameters governing behaviors of aggregated entities defined.	Tests defined for interoperability & correlation of aggregate entity behavior.	Correlated & validated high level behavior of aggregate entities assured.

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