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Communication Service Requirements For Distributed Interactive Simulation: Part 1, Application Service Characterization, Invesitgation Of OSI Protocols For Distributed Interactive Simulation

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Part 1: Application Service Characterization

Investigation of OSI Protocols for Distributed Interactive Simulation

Prepared for:
U.S. Army Project Manager for Training Devices

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COMMUNICATION SERVICE REQUIREMENTS FOR DISTRIBUTED INTERACTIVE SIMULATION

PART 1: APPLICATION SERVICE CHARACTERIZATION

PREPARED FOR:

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INVESTIGATION OF OSI PROTOCOLS FOR
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1.0 INTRODUCTION

The Communication Architecture and Security Subgroup (CASS) of the Distributed Interactive Simulation (DIS) Workshop on Standards for the Interoperability of Defense Simulations (SIDS) is developing a standard for the communication subsystem of DIS. This standard, **Communication Architecture for Distributed Interactive Simulation** (CADIS), defines the general requirements, patterns of communications, communication services and specific service requirements, and areas for future consideration. The communication subsystem service requirements discussed in CADIS fall into two categories: network related and application related. This report discusses the application requirements of DIS. (The network requirements will be evaluated in Part 2 of this study, due date 4/92.) The application requirements span a variety of parameters including multicast transmission and unreliable data transfer. The purpose of this paper is to establish the application service characteristics for both the required and recommended interim DIS Protocol Data Units (PDUs). Each of the DIS PDUs requires certain service characteristics to make its communication meaningful. These characteristics are grouped into broad classes of operation for DIS. After establishing the classes of service required, it is possible to postulate a communication architecture to support the DIS application.

This paper presents the following information: a brief introduction to DIS and the PDUs which comprise the application being analyzed; the communication service requirements developed by the DIS CASS, which form the basis for this study; an analysis of the service characteristics for each functional group of DIS PDUs; and a description of the broad classes of operation to satisfy the DIS environment.

2.0 DIS FUNCTIONAL REQUIREMENTS

Distributed Interactive Simulation (DIS) is an exercise involving the interconnection of a number of simulation and/or real devices in which the simulated entities are able to interact within a computer generated environment. The simulation or real devices may be present in one location or be distributed geographically. The simulations constantly interact by sending messages describing the current state of the simulation entities under their control, thereby allowing the other computers to incorporate state changes into their simulation. The messages which transmit state information between computers are application level Protocol Data Units (PDUs).

DIS functional requirements are to provide: Entity Information, Entity Interaction, DIS Management, and Environment Information. Within each functional category, PDUs have been defined or recommended to satisfy specific requirements. The September 1991 version of the

DIS standard defines ten required PDUs and six recommended interim PDUs.[1] The following sections, taken from Chapter 6 of the DIS standard, briefly describe each of the four functional requirements areas and their associated PDUs. For a more detailed explanation of the PDUs, refer to DIS Standard [1] and Rationale document [2]. A summary of the DIS functional requirements is presented in Table 1.

2.1 Entity Information

Because of the variety of simulated entities that can be involved in a single exercise, it is important to be able to communicate detailed information concerning each entity. This information includes the identity of the entity, its orientation, and how the entity should appear to others. In the September 1991 version of the DIS standard there is only one PDU which defines this information, the *Entity State* PDU.

2.2 Entity Interaction

During a simulation exercise, entities may interact. Entity's interaction may be represented by weapons fire, logistics support, collisions, or electronic interactions (e.g., radar or sonar). To represent this information, eleven PDUs have been embodied in the DIS standard. Only nine of these PDUs are required, the remaining two PDUs are interim recommendations.

2.2.1 Weapons Fire

When a simulated entity fires a weapon, its simulator must communicate the location of the firing weapon and the type of munition fired. Depending on the munition type, a determination of the detonation location may be made. Given the munition type and the location of detonation, all simulators assess their own damage. The DIS standard provides two PDUs to represent Weapon Fire: *Fire* and *Detonation*.

2.2.2 Logistics Support

Certain services, such as resupply or repair of vehicles, may be represented in a simulated exercise. These are provided by logistics support services. There are six PDUs which define logistics information: *Service Request*, *Resupply Offer*, *Resupply Received*, *Resupply Cancel*, *Repair Complete* and *Repair Response*.

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[1] The September version of the DIS standard specifies three recommended PDUs for Update Threshold Control. As of this writing, those PDUs have been removed from the standard and, therefore, will not be included in this study.

I. ENTITY INFORMATION
- A. Entity State (R)
  - 1. Entity State PDU

II. ENTITY INTERACTION
- A. Weapons Fire (R)
  - 1. Fire PDU
  - 2. Detonation PDU
- B. Logistics Support (R)
  - 1. Service Request PDU
  - 2. Resupply Offer PDU
  - 3. Resupply Received PDU
  - 4. Resupply Cancel PDU
  - 5. Repair Complete PDU
  - 6. Repair Response PDU
- C. Collisions (R)
  - 1. Collision PDU
- D. Electronic Interaction (NR)
  - 1. Emitter PDU
  - 2. Radar PDU

III. DIS MANAGEMENT
- A. Network Management (NR)
- B. Simulation Management (NR)
  - 1. Activate Request PDU
  - 2. Activate Response PDU
  - 3. Deactivate Request PDU
  - 4. Deactivate Response PDU
- C. Performance Measures (NR)

IV. ENVIRONMENT INFORMATION
- A. Changes in the Terrain (NR)
- B. Weather Conditions (NR)
- C. Degrees of Ambient Illumination (NR)
- D. Other Environmental Effects (NR)

TABLE 1
DIS Functional Requirements
Required (R) and Non-Required (NR) PDUs

2.2.3 Collisions

It is necessary to represent entity collisions in a simulation. When a collision occurs, the entities involved must be aware of the collision. Each determines its own damage based on the mass and velocity of the entities. The DIS *Collision* PDU furnishes this information.

2.2.4 Electronic Interaction

The development of technology in the area of electromagnetics and electro-optics has produced a variety of sensors and emitters ranging from ship's sonar to air defense radar. Representation of these devices is essential in a simulation exercise. The *Emitter* and *Radar* PDUs are included in the DIS standard, but are currently only interim recommendations.

2.3 DIS Management

Centralized control of a Distributed Interactive Simulation may be used to manage network hardware operation and certain aspects of a simulation exercise, and to allow gathering of data for performance measures. DIS management functions are divided into three categories: Network Management, Simulation Management and Performance Measures.

2.3.1 Network Management

Network management functions handle basic network functions such as load management, node and gateway monitoring, and network recovery. Analysis of network performance is also assessed here. There are no required or interim Network Management PDUs.

2.3.2 Simulation Management

There is a need for centralized control of the simulation exercise at each site participating in the simulation. Functions of simulation management include: Start, Restart, Maintenance, and Shutdown of the exercise. Other functions required include the introduction of late players and the collection and distribution of certain types of data. The DIS standard recommends four simulation management PDUs: *Activate Request*, *Activate Response*, *Deactivate Request* and *Deactivate Response*.

2.3.3 Performance Measures

The primary uses of distributed simulation are to train individuals to work as a team and to evaluate new hardware performance in a realistic operational scenario. In either case, some performance measures are required beyond those that can be gathered from responses transmitted over the communication medium. These measures include long term statistical data collection and site data collection for replay and evaluation. There are no required or recommended PDUs for performance measures.

2.4 Environment Information

For simulated entities to participate in the same exercise, they must share the same environment. Different types of information about the environment are necessary to make the exercise realistic. This information may include changes in the terrain, weather, ambient illumination, and other factors. There are no required or interim recommendations for environment information.

2.4.1 Changes in Terrain

Changes in the terrain can be caused by a number of factors. These include engineering effects, such as the construction of a bridge or a building; weapons effects, which could destroy objects (including those created via engineering effects), as well as change the shape of the terrain through the impact of shells or explosion of mines; and natural effects such as flooding, growth of vegetation, or changes due to forest fires.

2.4.2 Weather Conditions

Weather conditions can affect real life battles, and therefore should have an effect on simulated battles. Rain, snow, fog, and clouds should be represented in a simulated exercise. The wind's effect on a cloud of smoke that, in turn, affects vehicle visibility, and chemical's effect on people/soldiers should be considered as well.

2.4.3 Ambient Illumination

Night battles and day battles are to be simulated.

2.4.4 Other Environmental Effects

Other environmental effects should also be considered. The effect of a nuclear blast is one example. The effects of water temperature and salinity on the propagation of sound should be considered in marine environments.

3.0 DIS COMMUNICATION SERVICE REQUIREMENTS

The Communication Architecture and Security Subgroup (CASS) of the DIS workshop has developed a set of communication service requirements for the communication subsystem of the DIS standard [4]. These requirements are based on experience with state-of-the-art distributed simulation activities, as well as projections based on anticipated use and evolution of the technology base. The purpose of the communication subsystem for DIS is to provide an appropriate interconnected environment for effective integration of both locally and globally distributed simulation entities.

Distributed simulation environment support requires various types of communication. The communication requirements encompass control and data. Data communications, including voice, may be with or without real time requirements and will likely be augmented to include such things as video and other forms of pictorial information. It is desirable from a usage and communications management perspective for each of these forms of traffic to share communications facilities, instead of having disjoint facilities for each.

A summary of the communication service requirements developed by the CASS is shown in Table 2. The list is divided into application requirements and network requirements which reflects the scope of this study.

APPLICATION REQUIREMENTS	NETWORK REQUIREMENTS
Point-to-Point	Multicast Implementation
Multicast	Multicast Management
Broadcast	Real Time Operating Speeds
Reliable	Low Latency Packet Delivery
Unreliable	High Throughput
Real Time	Low Interpacket Dispersion for Voice/Video
Non-Real Time	Non-Blocking Interface
Small Packets	Authentication/Access Control
Bulk Transfer	Flow Control
	Security
	Flexible Entity Naming & Addressing

TABLE 2
Distributed Interactive Simulation Communication Service Requirements

3.1 Application Requirements

Each DIS PDU requires certain service characteristics to make its communication meaningful. The application requirements, shown in Table 2, will be used to define a model of the service types necessary to support communication. The service model developed from the PDU characterization will be used to develop the interface to the application and lower layers. (Note: This report does not define the application and lower layer interfaces. This subject will be covered in Part 2 of this analysis when the network requirements are analyzed.)

3.1.1 Definition of Terms

Broadcast Mode — A transmission mode in which a single message is sent to all network destinations, i.e. one-to-all. Broadcast is a special case of multicast.

Multicast Mode — A transmission mode in which a single message is sent to multiple network destinations. Typical multicast systems are based upon the precepts of connectionless data transmissions. This implies no error recovery or retransmission procedures are used if some stations do not receive a message. A reliable multicast ensures all active members of a multicast group receive a given message.

Non-Real Time Service — Any protocol function which does not require real time service. (see Real Time Service.)

Point-to-Point Mode — Sending information between two users of the network, i.e. one-to-one.

Real Time Service — A service which satisfies strict timing constraints imposed by the user of the service. The timing constraints are user specific and should be specified so that the user will not be adversely affected by any delays within the constraints. (DIS requires that 5% of all data be processed within 100ms and 95% be completed within 300ms, therefore the DIS real time threshold is 100ms.)

Reliable Service — A communication service in which data transmitted to a receiver is acknowledged. In reliable data transfer, the receiver only acknowledges validated data (validated using a check-sum). If data is not acknowledged, the transmitter periodically retransmits until an acknowledgement is received. This insures reliable transmission (delivered data is in sequence with no duplicates and no errors).

Unreliable Service — A communication service in which transmitted data is not acknowledged. Such data may never be received by the target, may be received out of order, and, if received, may be corrupt.

3.1.2 DIS PDU Service Characterization

The application services for required and recommended DIS PDUs are characterized in Tables 3 and 4, respectively. The analysis of application service requirements considers the following characteristics: reliable, unreliable, broadcast, multicast, point-to-point (P-to-P), and real time. Although data size (packets and bulk transfer) is included in the application requirements defined in Table 2, it is not presented in the summary tables for the following reason. Inter-entity communication in a distributed interactive simulation environment consists largely of packets sent between two or more of the simulation participants. These packets are usually small, <250 bytes, and constitute the majority of all PDU traffic. All PDUs listed in Table 3 and 4 fall into the "small packet" characterization. There are situations which mandate non-real time, point-to-point, reliable bulk transfer, however. Such situations arise when moving large items such as terrain database files or video images. The bulk transfers fall into the Network and/or Simulation Management functions, but there are currently no PDUs which reflect this type of interaction. Consequently, bulk transfer is considered a special case.

	Reliable	Unreliable	Broadcast	Multicast	P-to-P	Real Time
Entity State		*		*		*
Fire	*			*		*
Detonation	*			*		*
Service Request	*				*	*
Resupply Offer	*				*	*
Resupply Received	*				*	*
Resupply Cancel	*				*	*
Repair Complete	*				*	*
Repair Response	*				*	*
Collision	*				*	*

TABLE 3
Required DIS PDU Communication Services

	Reliable	Unreliable	Broadcast	Multicast	P-to-P	Real Time
Emitter	*			*		*
Radar	*			*		*
Network Management			*			
Simulation Management	*			*		
Activate Request	*				*	
Activate Response	*				*	
Deactivate Request	*				*	
Deactivate Response	*				*	
Performance Measures	*	*			*	

TABLE 4
Non-Required DIS PDU Communication Services

3.1.2.1 Entity Information

The PDU for Entity Information is listed in Table 5.

Entity State PDUs
Entity State

TABLE 5 Entity Information PDUs

The Entity State PDU (ESPDU) constitutes the bulk of network traffic for a simulation exercise. Currently, the appearance updates represented by the ESPDU are of most interest to exercise participants within a limited radius of the initiating entity. Any exercise participant which is not in the area of interest, but receives the ESPDU, will have to filter out unwanted information. Therefore, Entity State has a strong requirement for multiple one-to-many, also called multicast, interactions. Multicast interactions deliver identical packets to multiple recipients as part of a single sender operation. A multicast data transfer provides co-located entity groups the capability of communicating state information based on locale in the simulated exercise.

In addition to their multicast requirements, ESPDUs must be delivered in real time but do not need to be transmitted reliably. If ESPDUs were sent every time the entity changed position/orientation, they would be issued continuously, possibly overloading the network. Dead Reckoning (DR) algorithms are used to predict the entity's position over time, thereby reducing the need for continuous ESPDU generation. Application reliability requires more processing time to ensure destination acknowledgement. Due to the real time requirement of ESPDUs, reliability need only be a best effort. If an ESPDU is lost, the DR models used to reduce network traffic must also be able to account for the lost packet.

3.1.2.2 Entity Interaction

The PDUs for Entity Interaction are listed in Table 6.

Weapons Fire PDUs	**Logistics Support PDUs**	**Collision PDUs**	**Electronic Interaction PDUs**
Fire	Service Request	Collision	Emitter
Detonation	Resupply Offer		Radar
	Resupply Received		
	Resupply Cancel		
	Repair Complete		
	Repair Response		

TABLE 6 Entity Interaction PDUs

As shown in Table 3, Entity Interaction PDUs have varied characteristics. Within the Weapons Fire category, the Fire PDU (FPDU) and the Detonation PDU (DPDU) have the same service characterization. Similar to the ESPDU, both the FPDU and the DPDU have a strong multicast requirement. This requirement allows only those entities within the area of interest to receive information about weapons firing and detonation.

These PDUs also have a real time requirement, and must be more reliable than ESPDUs. Whereas ESPDUs can rely on DR to extrapolate position after packet loss, FPDUs and DPDUs are not as robust. When a weapon is detonated, it is crucial that everyone in the multicast group receive that information so "killed" targets do not continue to play in the exercise. Because of the high degree of reliability required for the DPDUs, a multicast service with reliability controls is necessary. Reliable DPDU transfer will require additional overhead to ensure data receipt. Consequently, real time delivery of DPDUs can not be guaranteed with this service. (The effect of non-real time DPDU delivery in a simulation will require further study.) The Fire PDU, however, requires reliability but no added delay. In a weapons fire interaction, it is more important to receive the DPDU reliably and the FPDU in real time.

The Logistics Support PDUs (i.e., Service Request, Resupply Offer, Resupply Received, Resupply Cancel, Repair Complete, and Repair Response) represent activities which, although long in duration, require real time service. The resupply and repair interactions require a simple

reliable transaction (request/reply) paradigm. The reliable transaction between entities only requires point-to-point transmissions between the service entities involved in the interaction. The Logistics Support PDUs do not require multicast, because entities in the multicast group are not interested in the service itself, only the ESPDUs which continue to be generated by the servicing entities. Therefore, the Logistics Support PDUs are characterized as requiring a point-to-point service with no added delay.

The last required category of PDUs in Entity Interaction is Collisions. Collision PDUs require a real time, point-to-point service. Again, only the entities involved in the collision will be interested in this information. Changes to entity appearance resulting from the collision will be communicated using ESPDUs. Due to the real time requirement, Collision PDUs are characterized as requiring reliability with no added delay.

The only category of PDUs not required for Entity Interaction is Electronic Interaction. Electronic Interaction consists of two recommended PDUs, Emitter and Radar. Both PDUs require a real time, multicast transmission with reliability but no added delay.

3.1.2.3 DIS Management

The PDUs for DIS Management are listed in Table 7.

Network Management PDUs	Simulation Management PDUs	Performance Measures PDUs
	Activate Request	
	Activate Response	
	Deactivate Request	
	Deactivate Response	

TABLE 7 DIS Management PDUs

There are no PDUs specified for Network Management. Conceptually, network management would be handled by a network management protocol (e.g., Simple Network Management Protocol or Common Management Information Protocol) and would not require DIS PDUs to accomplish the management of the physical network. Best effort broadcast messages can be used

for low-cost, system-wide management purposes.

The Simulation Management category of PDUs is responsible for the activation and deactivation of simulation players. The request to activate or deactivate entities in a simulation exercise (i.e., Activate and Deactivate Request and Response PDUs) can be achieved through acknowledged point-to-point packet service using a simple request-reply transaction to achieve a reliable transfer through retransmission on timeout. This service is characterized as a non-real time reliable point-to-point service. Other possible functions of Simulation Management include management and control messages spanning multiple exercises. This type of service requires non-real time multicast transmission with reliability controls. In addition to the packet form of interaction, there are situations which mandate non-real time, point-to-point, reliable bulk transfer. Such situations arise when moving large items such as terrain databases or video images.

To satisfy a Performance Measures functional requirement for reviewing and replaying training and evaluation simulation exercises, it must be possible to collect and save all network traffic pertaining to a particular exercise at a single site. This type of function requires a real time, reliable service. Performance Measures also include long-term statistical data collection. This type of function also requires a real time service.

3.1.2.4 Environment Information

The PDUs for Environment Information are listed in Table 8.

Changes in Terrain PDUs	**Weather Conditions PDUs**	**Ambient Illumination PDUs**	**Other Environmental Effects PDUs**

TABLE 8 Environment Information

Currently, there are no PDUs required or recommended for Environment Information. Consequently, it is difficult to determine which types of service are required. However, if PDUs are developed for this functional area, the required services will fall into one of the established service classes.

4.0 CONCLUSIONS

From the previously stated rationale, five service models emerge as characterizing the DIS application.

CLASS 1 **Multicast With Best Effort**
A mode of operation where the multicast service provider uses no added mechanisms for reliability except those inherent in the underlying service.

CLASS 2 **Multicast With Reliability Controls**
A mode of operation where the multicast service provider uses whatever mechanisms are available to ensure the data is delivered in sequence with no duplicates and no errors.

CLASS 3 **Multicast With Some Reliability And No Added Delay**
A mode of operation where the multicast service provider may elect to use some reliability features such as resequencing and error correction. The mechanisms must not involve delays in delivering correct data to the user. This means retransmissions are unacceptable since it would require two round-trip delays.

CLASS 4 **Point-to-Point With Some Reliability and No Added Delay**
A mode of operation where the point-to-point service provider may elect to use some reliability features such as resequencing and error correction. The mechanisms must not involve delays in delivering correct data to the user. This means retransmissions are unacceptable since it would require two round-trip delays.

CLASS 5 **Point-to-Point With Reliability Controls**
A mode of operation where the point-to-point service provider uses whatever mechanisms are available to ensure the data is delivered in sequence with no duplicates and no errors.

The communication architecture for DIS will have to support the established service classes. Now that the PDUs have been categorized, it is possible to postulate an architecture to support DIS. A communication architecture can only be evaluated as to whether it meets the needs of the application. From this analysis, the application needs are apparent and the analysis of network architecture requirements can begin. The service models are shown in Table 9.

• CLASS 1 • Multicast with Best Effort	• CLASS 2 • Multicast with Reliability Control	• CLASS 3 • Multicast with Some Reliability & No Added Delay	• CLASS 4 • Point-to-Point with Some Reliability & No Added Delay	• CLASS 5 • Point-to-Point with Reliability Control
Entity State	Detonation	Fire	Service Request	Activate Response
Network Managment	Simulation Management	Emitter	Resupply Offer	Activate Request
		Radar	Resupply Received	Deactivate Response
		Performance Measures	Resupply Cancel	Deactivate Response
			Repair Complete	Simulation Management
			Repair Response	
			Collision	
			Performance Measures	

TABLE 9
DIS Application Service Model

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