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Standard For Information Technology-protocols For Distributed Interactive Simulation Applications: Rationale

University of Central Florida Institute for Simulation and Training

INSTITUTE FOR SIMULATION AND TRAINING

RATIONALE

STANDARD FOR INFORMATION

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Simulation Applications

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Rationale
Standard for Information Technology - Protocols for Distributed Interactive Simulation Applications

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C O N T E N T S

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1. FOREWORD

As operational equipment has become increasingly complex and more expensive to operate, and as test/training range space has decreased, the U.S. military has found simulation to be a cost-effective means of training personnel and an aid in the design, development, and testing of material. Thus far, these simulations have been designed primarily to simulate one unit of operational equipment operating against one or more threats. These types of simulations are ideal for evaluating the operation of equipment or for training personnel to operate the equipment as a single entity. However, during the Iranian Rescue Mission and the Grenada Invasion, the military learned that coordinated actions between team members in different services and between different units of operational equipment are required in order to achieve the mission objectives.

One alternative means for providing a teamwork training and evaluation environment is to build a large simulation computer with multiple operator stations. A less expensive solution is to take the current inventory of individual operator trainers and developmental simulators and network them together.

A standard communications protocol must be developed in order for these dissimilar simulations to communicate with one another. The objective of the standard addressed in this rationale document is to define this communications protocol at the protocol data unit level.

Since the emerging standard is primarily concerned with interoperability, the concept of Open Systems has become an important issue. This subject has been dealt with quite thoroughly by the International Organization for Standardization (ISO), whose primary concern is the communication between heterogeneous computer systems developed by different vendors. ISO's efforts have led to the development of the Open Systems Interconnection (OSI) Reference Model. This rationale document was written with the assumption that the protocol will be implemented as part of the application layer of the OSI Reference Model.

1.1 History

The current work on standards began in August 1989 with the first workshop on Standards for the Interoperability of Defense Simulations.

The second workshop took place in January 1990. As a result of these workshops and subsequent subgroup meetings, over 50 position papers containing recommendations for the standard were submitted to the Institute for Simulation and Training (IST). Using the work of SIMNET (See Appendix B) as a baseline and considering recommendations made in workshop meetings and position papers, IST developed a first draft for a military standard which describes the form and types of messages to be exchanged between simulated entities in a Distributed Interactive Simulation. In response to the first draft standard, 13 position papers containing recommended changes and additions to the draft standard were submitted to IST.

The third workshop took place in August 1990 where these recommendations were considered and some adopted. As a result, IST has revised the first draft and published a second draft standard.

The fourth workshop took place in March 1991 to put the finishing touches on the draft standard. The fifth workshop took place in September 1991, and participants began working on the first revision of the second draft standard.

The sixth workshop took place in March 1992. Final recommendations were considered and some of them accepted. As a result, the second draft standard was revised and published as the final draft DIS standard in May 1992, which was also submitted to IEEE for approval.

The seventh workshop took place in September 1992. The newly developed Radio Communication, Simulation Management and Emission Regeneration PDUs were included in the standard to establish the framework of Version 2.0. This rationale document addresses the issues associated with the Version 2.0 of the standard as of Mrach 1993.

1.2 Institute for Simulation and Training

The Institute for Simulation and Training (IST) was formed in 1982 as a part of the University of Central Florida's Division of Sponsored Research. IST's purpose is to perform basic and applied research programs in state-of-the-art simulation and training systems. IST is also responsible for identifying the direction of simulation and training technology during the next decade.

2. SCOPE

This rationale document establishes the requirements and provides the rationale for the protocol data units (PDUs) associated with entity information, entity interactions and simulation management information that are exchanged between simulation applications interacting in a distributed interactive simulation. The DIS protocol encompasses a portion of the application layer of a communications architecture as defined by the International Organization for Standardization's (ISO) Open Systems Interconnection (OSI) Reference Model (see Appendix A1).

2.1 Application

This rationale document applies to the draft standard entitled STANDARD FOR INFORMATION TECHNOLOGY - PROTOCOL FOR DISTRIBUTED INTERACTIVE SIMULATION APPLICATIONS - VERSION 2.0, and is intended for interpretation and explanation of the above standard.

2.2 Intended Use

The intended use for this rationale document is four-fold:

a. To define Distributed Interactive Simulation (DIS) and its requirements.

b. To recommend a standard protocol that supports communication and interaction between simulation applications taking part in a distributed interactive simulation.

c. To recommend protocol data units (PDUs) to serve as interim requirements for areas of DIS that are not part of the entity information and entity interaction.

d. To present other interoperability issues that are related to DIS as they appeared in various position papers and working group recommendations.

2.3 Requirements

There are no requirements related to the use of this rationale document.

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3. REFERENCES

Some of the documents referenced in this rationale document are listed below.

3.1 Standards Referenced

The following standards have been referenced in this document:

- ISO 7498 and CCITT X.200 (OSI Reference Model)
- ISO 8824 & ISO 8825 (ASN.1 and BER)
- IEEE 754-1985 (Standard for Binary Floating Point Arithmetic)
- IST-CR-92-12 (Protocol Data Units for Entity Information and Entity Interaction in a Distributed Interactive Simulation (Version 2.0 - First Draft))
- IST-CR-93-02 (Enumeration and Bit Encoded Values for Use with Protocols for Distributed Interactive Simulation Applications)
- IST-PD-91-01 (Protocol Data Units for Entity Information and Entity Interaction in a Distributed Interactive Simulation (Final Draft - May/92))

3.2 Other Documents Referenced

The following non-standard documents have been referenced in this document:

- Pope (BBN), The SIMNET Network and Protocols, BBN Report No. 7102, July 1989.

- Kanarick & Pope (BBN), "Summary of SIMNET Protocol Changes", Jan. 1990

- Tannenbaum, Computer Networks. Prentice Hall: 1988.

- (various) Summary Report: The First Conference on Standards for the Interoperability of Defense Simulations, IST Report No. IST-CR-89-1, Aug.1989.

- (various) Summary Report: The Second Conference on Standards for the Interoperability of Defense Simulations, IST Report No. IST-CF-90-01, Jan. 1990.

- (various) Summary Report: The Third Workshop on Standards for the Interoperability of Defense Simulations, IST Report No. IST-CR-90-13, Aug. 1990.

* (various) Summary Report: The Fourth Workshop on Standards for the Interoperability of Defense Simulations, IST Report No. IST-CR-91-11, March 1991.

* (various) Summary Report: The Fifth Workshop on Standards for the Interoperability of Defense Simulations, IST Report No. IST-CR-91-13, Sept. 1991.

* (various) Summary Report: The Sixth Workshop on Standards for the Interoperability of Defense Simulations, IST Report No. IST-CR-92-2, March 1992.

* (various) Summary Report: The Seventh Workshop on Standards for the Interoperability of Defense Simulations, IST Report No. IST-CR-92-17, Sept. 1992.

3.3 Position Papers

These papers contain recommendations to be included in the standard. See Appendix B for a complete list of position papers. Copies of the position paper texts can be found in the Workshop Summary Reports.

3.4 History of Conferences on Standards for the Interoperability of Defense Simulations

3.4.1 Second Conference on Standards for the Interoperability of Defense Simulations

On August 22-23, 1989, the First Conference on Standards for the Interoperability of Defense Simulations was held to begin the process of developing a draft standard. The two-day workshop focused on Network Communications and Terrain Databases. A summary of the workshop activities is found in Appendix D.

3.4.2 Secod Conference on Standards for the Interoperability of Defense Simulations

On January 15-17, 1990, the Second Conference on Standards for the Interoperability of Defense Simulations was held to continue discussion on interoperability issues, many of which are presented in this rationale document. Some of the position papers in Appendix B were submitted for this workshop and other papers were submitted as a direct result of this meeting. A summary of the workshop activities is included in Appendix D.

3.4.3 Third Workshop on Standards for the Interoperability of Defense Simulations

On August 7-8, 1990, the Third Workshop on Standards for the Interoperability of Defense Simulations was held to examine the draft standard published in June 1990 and to continue the discussions on interoperability issues. A new working group was formed called the Performance Measures Working Group. Its purpose is to deal with issues related to human and equipment performance measures. Thirteen position papers were submitted in response to the June draft of the standard, nine of which were presented during the workshop. A list of these papers has been added to Appendix B. A summary of the workshop activities is included in Appendix D.

3.4.4 Fourth Workshop on Standards for the Interoperability of Defense Simulations

On March 13-15, 1991, the Fourth Workshop on Standards for the Interoperability of Defense Simulations was held to examine the January 1991 revised draft standard and to continue discussion on other interoperability issues not addressed in the draft standard. Seven position papers were submitted in response to the January draft standard, all of which were presented during the workshop. A summary of the workshop activities is included in Appendix D.

3.4.5 Fifth Workshop on Standards for the Interoperability of Defense Simulations

On September 24-26, 1991, the Fifth Workshop on Standards for the Interoperability of Defense Simulations was held to identify new PDUs for Revision 1 of the draft standard. In addition, interoperability issues related to Performance Measures, correlation of environment information, and communication architecture were addressed. The Communication Architecture and Security Subgroup presented a draft standard for review and the Performance Measures Group (now called the Fidelity, Exercise Control, and Feedback Requirements working group) produced a preliminary draft standard. Position papers were discussed within the subgroups to which they pertained. Fourteen position papers were presented in all. A summary of the workshop activities is included in Appendix D.

3.4.6 Sixth Workshop on Standards for the Interoperability of Defense Simulations

On March 17-19, 1992, the Sixth Workshop on Standards for the Interoperability of Defense Simulation was held to debate the final changes to the DIS PDU Draft Standard Version 1.0 (IST-PD-91-01), which was also submitted to IEEE for balloting and approval. In addition, the Interface Time Mission Critical group formed subgroups to start the draft DIS PDU Standard Version 2.0 that will include Simulation Management, Radio Communication and Emission Regeneration capabilities. The Communication Architecture and Security Subgroup worked on a preliminary draft standard for submit its recommendations for version 1.0 of the DIS Communications Architecture standard. The Fidelity, Exercise Control and Feedback requirements group worked on the preliminary draft standard. The Environment group worked on the database correlation issues after the P1278-SIF standard (Draft Military Standard Simulator Data Base (SSDB) Interchange Format (SIF) for High Detailed Input/Output (SIF/HDI) and Distributed Processing (SIF/DP).

3.4.7 Seventh Workshop on Standards for the Interoperability of Defense Simulations

On September 21-24, 1992, the Seventh Workshop on Standards for the Interoperability of Defense Simulation was held to review the first draft of the DIS PDU Standard Version 2.0 (IST-CR-92-12). In addition, a few recommendations made by the IEEE balloters were presented to the ITSC group for ballot. The Communication Architecture and Security sub-group presented the Communication Architecture standard for DIS and discussed refinements to that document. The newly formed Field Instrumentation group produced a preliminary Field Instrumented PDU standard to address its particular requirements for DIS. The former FECFR group was split into two groups: The Fidelity group and the Exercise Control Feedback Requirement (ECFR) group. The Fidelity group produced a preliminary Fidelity standard document and discussed issues related with target/background contrast and line-of-sight intervisibility. The ECFR group reviewed the DIS PDU standard and forwarded its recommendations to the Simulation Management subgroup for further capabilities.

4. ACRONYMS & DEFINITIONS

4.1 Acronyms Used in This Document

The acronyms used in this document are defined as follows:

AAW	-	Anti-Air Warfare
ASCII	-	American Standard Code for Information Interchange
ASW	-	Anti-Submarine Warfare
BAM	-	Binary Angle Measurement
BFIT	-	Battle Force In-port Trainer
CASS	-	Communication Architecture and Security Subgroup
CWI	-	Continuous Wave Illuminations
C3	-	Command, Control and Communications
DARPA	-	Defense Advanced Research Projects Agency
DIS	-	Distributed Interactive Simulation
DRN	-	Data Representation Notation
ECM	-	Electronic Countermeasures
EWSM	-	Electronic Warfare Support Measures
EW	-	Electronic Warfare
FECFR	-	Fidelity, Exercise Control, and Feedback Requirements
HF	-	High Frequency
IEEE	-	Institute of Electrical and Electronic Engineers
IFF	-	Identify Friend of Foe
IR	-	Infrared
ISO	-	International Organization for Standardization
IST	-	Institute for Simulation and Training

ITD	-	Interim Terrain Database
ITMC	-	Interface & Time/Mission Critical
LAN	-	Local Area Network
NIST	-	National Institute for Standards and Technology
OSI	-	Open Systems Interconnection
PDU	-	Protocol Data Unit
STRICOM	-	Army Project Manager for Training Devices
PRF	-	Pulse Repetition Frequency
SAFOR	-	Semi-Automated Forces
SIMAN	-	Simulation Management
SIMNET	-	Simulator Networking
STRICOM	-	Simulation, Training and Instrumentation Command
UTSS	-	Universal Threat System For Simulators
WAN	-	Wide-Area Network

4.2 Definitions

4.2.1 Application (Layer 7). The layer of the ISO reference model (ISO 7498) which provides the means for user applications to access and use the network's communications resources.

4.2.2 Application Layer Entities. The user application processes existing in the application layer of a communications architecture.

4.2.3 Application Layer Protocol. A set of rules by which the inter-process communication between corresponding Application Layer entities is accomplished.

4.2.4 Binary Angle Measurement (BAM). A method of angle measurement which uses the binary number system. Two types of angles are used in this document:

a. 32-bit BAMs. 32-bit BAMs are used to express the orientation of an entity. Each unit of BAM is equal to 360/2^32 degrees or 2*π/2^32 radians.

b. 16-bit BAMs. 16-bit BAMs are used to express the orientation of articulated parts. Each unit of BAM is equal to 360/2^16 degrees or 2*π/2^16 radians.

This method of angle measure is used when integers are required to express angle measure with high precision.

4.2.5 Bit. The smallest unit of information in the binary system of notation.

4.2.6 Broadcast. An addressing mode in which a PDU of a single application process is sent to all nodes on a network.

4.2.7 Byte. A sequence of eight consecutive bits operated upon as a unit.

4.2.8 Connectionless Service. A message service which provides a mode of information transfer between peer entities in which each data transfer is independent of and not coordinated with previous or subsequent transfers, and in which no state information is maintained.

4.2.9 Consultative Committee for International Telephony and Telegraphy (CCITT). An international standards group of the International Telecommunications Union, a specialized agency of the United Nations Organization.

4.2.10 Data Representation Notation (DRN). A syntax employed in SIMNET architecture to define data structures.

4.2.11 Dead Reckoning. A methodology for the estimation of the position/orientation of an entity based on a previously known position/orientation and estimates of time and motion.

4.2.12 Distributed Interactive Simulation (DIS). A time and space coherent synthetic representation of world environments designed for linking the interactive, free play activities of people in operational exercises. The synthetic environment is created through real-time exchange of data units between distributed, computationally autonomous simulation applications in the form of simulations, simulators, and instrumented equipment interconnected through standard computer communicative services. The computational simulation entities may be present in one location or may be distributed geographically.

4.2.13 Distributed Simulation. See Distributed Interactive Simulation.

4.2.14 Emitter. A device that is able to discharge detectable electromagnetic or acoustic energy.

4.2.15 Entity. See Simulation Entity.

4.2.16 Euler Angles. A set of three angles used to describe the orientation of an entity as a set of three successive rotations about three different orthogonal axes (x, y, and z). The order of rotation is first about z by angle Ψ (psi), then about the new y by angle Θ (theta), then about the newest x by angle Φ (phi). Angles Ψ and Φ range between $\pm\pi$, while angle Θ ranges only between $\pm\pi/2$ radians. These angles specify the successive rotations needed to transform from the world coordinate system to the entity coordinate system. The positive direction of rotation about an axis is defined by the right-hand rule.

4.2.17 Exercise. See Simulation Exercise.

4.2.18 Fields. A series of contiguous bits treated as an instance of a particular data type that may be part of a higher level data structure.

4.2.19 Multicast. An addressing mode in which a PDU of a single application process is sent to a subset of the nodes on a network.

4.2.20 Network Management. The collection of administrative structures, policies, and procedures which collectively provide for the management of the organization and operation of the network as a whole.

4.2.21 Node. A general term denoting either a switching element in a network or a host computer attached to a network.

4.2.22 Octet. A sequence of eight bits, usually operated on as a unit.

4.2.23 Protocol. A set of rules and formats (semantic and syntactic) that determine the communication behavior of simulation applications.

4.2.24 Protocol Data Unit. A unit data that is passed on a network between simulation applications.

4.2.25 Right-Hand Rule. Positive rotation is clockwise when viewed toward the positive direction along the axis of rotation.

4.2.26 Simulation Application. The executing software on a host computer that generates one or more simulation entities. The simulation application represents or "simulates" real-world phenomena for the purpose of training or experimentation. Examples of simulation applications include manned vehicle simulators, computer generated forces, and computer interfaces between a DIS network and real equipment. The simulation application receives and processes information concerning entities created by peer simulation applications through the exchange of DIS PDUs. More than one simulation application may simultaneously execute on a host computer. The simulation application is the application layer protocol entity that implements the protocol defined in this document. This document will use the term "simulation application" to avoid confusion between protocol entities and simulation entities. The term "simulation" may also be used in place of simulation application.

4.2.27 Simulation Entity. An element of the synthetic environment that is created and controlled by a simulation application through the exchange of DIS PDUs. Examples of types of simulated entities are: tank, submarine, carrier, fighter aircraft, missiles, bridges, or other elements of the synthetic environment. It is possible that a simulation application may be controlling more than one simulation entity. Simulation entities may also be referred to as "entities" in this document.

4.2.28 Simulation Exercise. An exercise that consists of one or more interacting simulation applications. Simulations participating in the same simulation exercise share a common identifying number called the Exercise Identifier. These simulations also utilize correlated representations of the synthetic environment in which they operate.

4.2.29 Simulation Management. A mechanism that provides centralized control of the simulation exercise. Functions of simulation management include: start, restart, maintenance, shutdown of the exercise, and collection and distribution of certain types of data.

4.2.30 <u>Tracked Munition</u>. A munition for which tracking data is required. A tracked munition's flight path is represented by Entity State PDUs.

5. DESCRIPTION OF FUNCTIONAL REQUIREMENTS FOR DIS

The following sections give a detailed description of the functional requirements for DIS. Included with these descriptions is an occasional discussion of SIMNET's implementation, and a brief summary of related position papers, followed by the recommendation being made for the standard where a recommendation is appropriate.

5.1 Entity Information

5.1.1 Introduction. Because of the great variety of simulated entities that might be involved in a single exercise, it is necessary to uniquely identify each entity in a particular simulation exercise and to provide a physical determination of the entity. The following paragraphs describe the information required to simulate entities in DIS. This information includes identification, classification, appearance, and location and orientation. All of this information must be communicated to the other entities participating in the exercise.

5.1.2 Identification Number. The unique identification of each entity in an exercise is performed by assigning a distinct number to each entity a distinct number. A flexible numbering system is required because two subsequent exercises will seldom have the same participants.

5.1.2.1 SIMNET Implementation. The SIMNET protocol allows for a unique identification of entities in an exercise in the following manner. All sites participating in an exercise are assigned a unique identification number. All host computers participating at each site are also assigned a unique identification number. Because each host may be simulating more than one entity, each host assigns a number to each entity that it is simulating. The unique identification for each entity, therefore, consists of a site identification, a host identification, and a simulated entity identification. This identification is called the Vehicle Identifier and is described in BBN Report No. 7102 Section 5.1.21.

5.1.2.2 Recommendation for the Standard. The recommendation for the standard is that each entity in a simulation exercise be uniquely identified by a distinct number such as that described above. This identification format, called the Entity Identifier Record, is described in detail in Section 5.3.8.2 of the standard.

5.1.3 Classification of Entities. The classification of entities as specific types allows information specific to a type to be described.

5.1.3.1 <u>Entity Type</u>. All entities participating in an exercise must be uniquely identified by classifying them into entity types.

5.1.3.1.1 <u>SIMNET Implementation</u>. SIMNET protocol classifies all objects into five categories: vehicle, munition, structure, life form, and other. This object type code is currently defined for vehicles and munitions. More details on object type can be found in BBN Report No. 7102 Section 5.1.8 and Appendices B and C.

5.1.3.1.2 <u>Position Papers</u>. Position paper [7] expresses concern about the adequacy of the SIMNET Object Type code to define additional types of entities within a previously defined format. Position paper [7] proposes that the SIMNET Object Type be expanded in size to accommodate present and future needs of additional platform and munitions types. The paper states that a change of this type would not have a significant impact on present network traffic.

5.1.3.1.3 <u>Working Group Recommendations</u>. At the Third Workshop, a hierarchical approach was recommended to allow lower fidelity simulations to depict a generic fighter aircraft while higher fidelity simulations will depict an F-14D.

5.1.3.1.4 <u>Working Group Recommendations (Fifth Workshop)</u>. At the Fifth Workshop it was recommended that the format expressing entity types be more consistent so that different countries have similar numerical representations for similar platform entities.

5.1.3.1.5 <u>Recommendation for Expressing Entity Type</u>. In DIS, the recommendation for the standard is that entities be of five types: platform, munition, life form, environmental, and cultural feature. The platform type includes all vehicles. The munitions type encompasses all types of weapon systems, including ballistic ammunition, decoys, chaff, mines, and guided munitions. Life form types in DIS are normally units of dismounted infantry, but a means to generate any group of life forms is provided. The environmental entities may include clouds, smoke, and biologics. Cultural features include engineering, weapons, and natural effects (such as craters, earth mounds, and vehicle tracks as well as damage to buildings, trees, and bridges). Section 5.4.1 provides further details on cultural features. These designations are accomplished using an Entity Type Record, described in detail in Section 5.3.10 of the standard. A hierarchical listing of Entity types appears in Appendices H1 and H2 of the standard. The format of Appendix H2 was revised for the October 1991 edition of the draft standard in order to include the recommendation in 5.1.3.1.4 above.

5.1.4 <u>Visual Appearance of Entities</u>. A simulator periodically reports physical appearance information about an entity it is simulating so that other simulators may correctly depict that entity. This information consists primarily of visual appearances.

Each entity has certain appearances that are unique to the particular type of entity it represents. These are described in the paragraphs which follow.

5.1.4.1 Platforms. Once the entity has been established as a platform, some general visual appearances can be defined. Information that must be communicated includes any special markings on the platform, location and orientation of the platform, all of its articulated parts, the platform's state (normal, on fire, smoking and so forth), and any external stores.

5.1.4.1.1 Environment and Visual Platform Appearances. The specific environment in which the platform operates allows more specific platform appearances to be defined. Most platforms can be described as operating on land, in the air, above or below the surface of the water, or in space. For example, for most land platforms, information such as the presence of engine smoke, dust clouds being raised by the platform, the paint scheme, any appendages to the platform, and launcher elevation can be described. For air platforms, information such as status of afterburners, status of running lights, and status of speed brakes can be used as cues to participants in the exercise. Information such as the status of navigational lights, presence of visual signaling, and bow wake caused by surface platform movement will affect the appearance description. The presence of a raised periscope on subsurface platforms must be communicated to all participants.

5.1.4.2 Life forms. Dismounted infantry with their anti-tank and anti-air weapons play a major role in modern land battles. DIS must incorporate the capabilities and limitations of dismounted infantry into the simulation in order to provide effective training or equipment effectiveness evaluations.

5.1.4.2.1 Visual Appearance of Life Forms. In describing the visual appearance of life forms in the simulation, information such as unit size, weapons carried by the unit, and concealment position need to be transmitted. As additional categories of life forms are defined, further appearance definitions will be generated.

5.1.4.2.2 Life Form Categorized by Weapon Carried. Since the purpose of life forms is to fire a weapon (such as a dragon missile), the life forms are depicted based on the primary weapon carried. In order to function in DIS, the unit should be treated in the same manner as a platform with an Entity State PDU containing position, velocity, appearance, and so forth. The appearance and detection distance would be affected by whether the unit is standing, kneeling, or prone. Damage to the unit (number of casualties) from weapons fire would also be affected by standing, kneeling, or prone position.

5.1.4.3 Munitions. Munitions are categorized as guided, ballistic, and fixed. (see section 5.2.1.2). Guided munitions tend to have longer flight times and unpredictable flight paths. Consequently, guided munitions must send out Entity State PDUs during their flight. Ballistic munitions tend to have shorter flight times and to follow ballistic trajectories. Consequently, ballistic munitions will not send out Entity State PDUs. In those rare instances when another host computer wishes to depict the appearance of the ballistic munition, it can calculate the munition position over time, based on initial location and velocity vector. Fixed munitions such as mines will be visible unless covered up. Consequently, fixed munitions will send out Entity State PDUs periodically to notify other host computers of their location.

5.1.4.4 Environmental Entities. The visual appearance of environmental entities depends on the specific type of environmental entity present. Five levels of size and density can be defined for each type of environmental entity. Once the environmental type, location, size, and density are known, the visual appearance can be depicted. For example, a school of fish can be depicted at a certain location, with a density and size value. All simulators can then depict that environmental entity according to their databases of information.

5.1.4.5 Cultural Features. By describing some cultural features as entities, variations in their appearance and location can be defined. The specific type of cultural feature will determine the individual characteristics that are used to depict its visual appearance. When changes to these cultural features occur, information detailing the change must be communicated. This information will include the feature type, destruction, creation and displacement time, the change type (man-made or natural), and the new location of the feature. In order to modify the position of a cultural feature, its new position and size must be specified so that it may be visually and electronically depicted. A range of sizes can be determined to indicate the sizes of an object. These sizes can be predetermined for all cultural feature entities.

5.1.4.6 SIMNET Implementation. The SIMNET protocol expresses entity appearance in the Appearance Field of the Vehicle Appearance PDU (VA PDU). This information applies to vehicles only. This field describes modifications to a vehicle's basic appearance. Details concerning appearances currently defined are found in BBN Report No. 7102, page 87.

5.1.4.7 Recommendations for Visual Appearances of Entities.

5.1.4.7.1 Platforms. The recommendation for the standard is that the basic appearances of platform entities be based on the platform type and specifically defined in an Appearance field of the Entity State PDU. Details on the Entity State PDU are in Section 5.4.3.1

of the standard. Definitions for appearances are detailed in Appendix D of the standard (IST-PD-91-01).

5.1.4.7.2 Life Forms. The recommendation for the standard is that life forms in DIS be represented in a manner similar to that of platforms. Life form types will be based on the weapon employed by that life form. See Appendix H1 of the standard (IST-PD-91-01) for defined life form types and Appendix D of the standard (IST-PD-91-01) for possible appearances.

5.1.4.7.3 Environmental Entity. The recommendation for the standard is that the visual appearance of an environmental entity be represented using the Appearance Field of the Entity State PDU to represent its size and density. See Appendix D of the standard (IST-PD-91-01) for defined environmental appearances.

5.1.4.7.4 Cultural Features. The recommendation for the standard is that some cultural features be represented as entities in order to allow variations in their appearance and location. Cultural features would be predefined as entities before the start of the simulated exercise. As entities, these cultural features will transmit Entity State PDUs to indicate whether they are to appear normal, on fire, or destroyed. Defined cultural features are found in Appendix H1 of the standard (IST-PD-91-01). Appearances for cultural features are found in Appendix D of the standard (IST-PD-91-01).

5.1.5 Electromagnetic/Acoustic Appearance. In addition to visual appearances, an entity may be able to emit electromagnetic energy that can be detected by the sensors of other entities, requiring each host computer to periodically transmit the information necessary for simulation of the electromagnetic or acoustic appearance of the entity.

5.1.5.1 Environment and Electromagnetic/Acoustic Appearance. Besides its importance for visual appearance information, a secondary reason for including the environment of an entity and the portion of the electromagnetic spectrum used by its emitters is to allow the host computer to quickly discard information about entities that cannot be seen or sensed by that particular entity. For example, a tank crew would not be concerned about propeller sounds or very low frequency radio transmissions issued from a submarine.

5.1.5.2 Platforms. In describing a platform's electromagnetic and acoustic appearance, information such as emitter capability, speed, and temperature is needed. Some electromagnetic and acoustic appearances are specific to platforms that operate in different environments. For subsurface platforms, the operation of equipment, the blowing and flooding of tubes, and the movement of the dive planes may all cause detectable sounds.

5.1.5.3 Life Forms. As a general rule, life forms emit only infrared and acoustic energy. However, the weapons, communications equipment, and sensors carried by life forms may emit in all electromagnetic regions.

5.1.5.4 Munitions. The appearance of munitions is primarily electromagnetic in nature and is, therefore, dependent on its radar return and the emitters it carries. By transmitting information about the munition's position, other entities able to detect the munition can simulate the position on their sensors. Other details about the munitions appearance may be obtained by transmitting the emitter type and mode.

5.1.5.5 Environmental Entities. As a general rule, environmental entities emit only infrared and acoustic energy.

5.1.5.6 Cultural Features. Any cultural feature that is emitting detectable electromagnetic or acoustic energy must transmit information to other entities who might be able to detect the emission. Cultural features, such as buildings serving as command posts, will emit a wide spectrum of electromagnetic energy.

5.1.5.7 The Emitter PDU and the ACME Radar PDU. In the June 1990 draft of the standard, the Emitter PDU was recommended for representation of emission of electromagnetic/acoustic appearances. In response to this recommendation, Position Paper [56] was submitted to IST and presented at the Interface & Time/Mission Critical Subgroup meeting in July 1990 (see Appendix C2) and also at the August 1990 Workshop (see Appendix D3). Position Paper [56] pointed out that the database for use of the Emitter PDU did not exist and a need existed to represent radar information in current implementations. The ACME Radar PDU was revised and presented as an interim solution until the databases for use with the Emitter PDU could be developed.

5.1.5.8 The Fourth & Fifth Workshop Recommendations for Emissions. Discussions concerning the Emitter PDU, the Radar PDU and the representation of electronic emissions in a DIS exercise continued in the Interface & Time/Mission Critical Subgroup. This group recommended that the Radar PDU and the Emitter PDU not be a requirement for the draft standard, but that they be included in Section 6 of the standard document so that they may be used if desired. The topic was recommended for further study by a new sub subgroup to deal with the issue. The special group is called the Emitter Group. This group met in July 1991 to determine a DIS strategy for handling emissions. Recommendations for several PDUs were made at the Fifth Workshop in September 1991. Further work of the Emission subgroup will be included in Revision 1 of the draft standard (IST-PD-91-01).

5.1.5.9 Recommendations for Electromagnetic/Acoustic Appearances of Entities. The recommendation for the requirements Section of the draft standard (Section 4 & 5) is that no PDUs be required for the representation of Electromagnetic/Acoustic Appearances. The Emitter PDU and the Radar PDU are included in the draft standard as a recommended option for the representation of electromagnetic/acoustic emissions of entities (See Section 6.4 of the standard (IST-PD-91-01)).

5.1.5.10 The Sixth and Seventh Workshop Recommendations for Emissions. In the Sixth Workshop, the recommendation was that both emission and radar capabilities be supported by the Emission PDU described in Sections 4 and 5 of the DIS PDU Standard as required PDUs. The existing Emission and Radar PDUs in Section 6 was deleted from the standard. A new Laser PDU was created to provide lazing capabilities. The DIS PDU Draft Standard Version 2.0 (IST-CR-92-12), which included the Emission and Laser as required PDUs, was released at the Seventh Workshop for review and discussion.

5.1.5.11 Recommendation for Munition Appearance. The electromagnetic appearance of a munition entity will be represented by using the Emitter PDU or by the PDU recommended by the Emission Subgroup. The recommendation for the standard (if the Emitter PDU is used) is that the appearance of a munition be represented in the following manner:

a. If the munition is one for which in-flight data is required or if the munition is fixed, Emitter PDUs should be issued so entities possessing sensors are able to represent the position of the munition when that position is detectable. In addition, an Emitter PDU will be issued every time the mode of an emitter changes (for example, search to track mode).

b. If the munition is ballistic or one for which in-flight data is not required, no PDUs should be issued for the munition. Entities should use information in the Fire PDU associated with the launch of the munition to determine whether the munition is detectable and, if detectable, determine its trajectory for sensor simulation. If the munition has active emitters, an Emitter PDU will be issued every time the mode of an emitter changes.

5.1.6 Location: World Coordinates. A location in the simulated world is specified using a three dimensional coordinate system.

5.1.6.1 SIMNET Implementation. In the SIMNET protocol, each coordinate is expressed as a 64-bit floating point number, measuring a distance in meters along one axis of the world coordinate system. The SIMNET world coordinate system is defined using Cartesian coordinates, with the southwest corner of the battlefield defined as (0,0,0) (Topocentric Coordinates). The x-direction is defined as east, the y-direction as north, and the z-direction is height above sea level.

5.1.6.2 Coordinate Systems. The alternatives for position reporting in a distributed simulation environment fall roughly into two categories. One category is some variant of latitude-longitude-altitude, with latitude and longitude measured in degrees of arc, and altitude measured in linear units. The other is an earth-centered orthogonal Cartesian coordinate system with mutually perpendicular x, y, and z axes, each measured in linear units. (See Position Papers [1], [11], and [41].)

5.1.6.2.1 Latitude-Longitude. Position reporting with latitude and longitude implies angular measure. If degrees of arc are used, a notation equivalent to an IEEE 64-bit float must be used for the angular measure in order to obtain a suitable degree of accuracy. Using the so-called binary angle measurement (BAMs) (see Section 6.3), suitable accuracy may be obtained with 32 bits. The drawback with both of these approaches is that transcendental functions must be used for range calculations. Both approaches are computationally expensive.

5.1.6.2.2 Topocentric Cartesian. A topocentric Cartesian coordinate system assumes a flat earth with surface-based x and y axes. While acceptable for land-based vehicles or nap-of-the-earth flying, errors are introduced when this system is applied to exercises involving large geographical areas or high-altitude flying (see Position Paper [26]).

5.1.6.2.3 WGS-84. The earth is not a true sphere. Modeling it as such introduces errors into position calculations. The shape of the earth is more of an ellipsoid. The most recent and most accurate model of the earth's shape is the World Geodetic System 1984 survey, an earth-centered and earth-fixed coordinate system (see Position Papers [17] and [38]).

5.1.6.2.4 Geocentric Cartesian. Using an orthogonal Cartesian coordinate system allows range calculations to be made using the theorem of Pythagoras, which incurs far fewer floating point operations than does transcendental function calculation (see Position Papers [17] and [38]). Position could be reported by a signed 32-bit integer, which has a range of 2^31 - 1 = +/- 2,147,483,647. This would allow measurement of 21,475 kilometer with a 1 centimeter accuracy, which, after subtracting the radius of the earth, yields an envelope of 9,380 miles. This method, however, falls short of including geosynchronous orbit and may not offer enough resolution for engineering simulators (see Position Paper [53]). Position Paper [57] recommends the use of floating point numbers. This recommendation was accepted at the August 1990 workshop.

5.1.6.2.5 Recommendation for the Standard. The recommendation for the standard is that location be reported in Geocentric Cartesian Coordinates, with position represented in meters from the center of the earth in mutually perpendicular x, y, and z directions. Each component of the position vector should be represented as a 64-bit floating point number. World coordinates are specified by a World Coordinates Record and are described in detail in Section 5.3.21 of the standard.

5.1.7 Velocity. Associated with an entity's position is its velocity. Velocity information is required for dead reckoning algorithms used to model the positions of entities.

5.1.7.1 SIMNET Implementation. SIMNET protocol defines linear velocity in meters per second along each of the world coordinate system's three axes. This is described by the basic data element Velocity Vector. See BBN Report No. 7102 Section 5.1.25 for more information on the Velocity Vector data element.

5.1.7.2 Recommendation for the Standard. The recommendation for the standard is that an entity's velocity be defined in meters per second along each of the world coordinate system's axes using a vector consisting of three 32-bit floating point numbers. Velocity is specified by the Linear Velocity Vector Record and is described in detail in Section 5.3.20.3 of the standard.

5.1.8 Entity Orientation and Angular Velocity. Orientation of an entity is represented by a series of three angles representing the rotations required to transform from the world coordinate system to the entity coordinate system. The rate at which an entity's orientation changes is given by the angular velocity about the entity's coordinates. This rate will provide additional information for simulations using higher order dead reckoning algorithms.

5.1.8.1 SIMNET Implementation. SIMNET protocol defines an entity's orientation using a nine element rotation matrix. The protocol does not specify angular velocity.

5.1.8.2 Use of Quaternions vs. Euler Angles. Euler angles were introduced in the June 1990 draft standard as an alternative to the nine element rotation matrix used in SIMNET in order to conserve bits in the Entity State PDUs. Position Paper [52] was submitted for consideration in response to the recommendation of Euler Angles for representing orientation. This position paper was also presented to the August 1990 workshop. The paper points out the advantages of using quaternions over Euler angles. These advantages include: simplified extrapolation of position (dead reckoning), no singularities, no transcendental functions required, more computational efficiency, and no numerical integration with attendant errors. There was much discussion in the Interface & Time/Mission Critical Subgroups concerning the use of quaternions.

The subgroup voted to support the use of Euler Angles in the standard. (See Appendix D3 for recommendations from the August 1990 workshop.)

5.1.8.3 Recommendation for the Standard. The recommendation for the standard is that an entity's orientation be specified as three angles in terms of a standard world coordinate system. The form of these angles is specified as an Euler Angles Record and is described in Section 3.2(12) and 5.3.11 of the standard. It is also recommended that angular velocity about the entity's coordinates be defined as three values representing BAMs per second. This is specified in the Angular Velocity Vect[illegible] and is described in detail in Section 5.2.2 of the sta[illegible].

5.1.8.4 DIS Tiger Team Recommendation for the Standard in Result of IEEE Balloting Process (12/92). It was recommended that Euler angles be represented as 32-bit floating point number in Radians and angular velocities be represented as 32-bit floating point numbers in Radians/second. The concept of BAM has been deleted from the DIS PDU standard.

5.1.9 Articulated Parts. For entities with articulated parts, the orientation of each degree of freedom must be communicated between platforms. A degree of freedom is a rotation about or a translation along an axis. An aileron, for example, has one degree of freedom as it rotates about its hinge. A tank cannon has two degrees of freedom: turret azimuth and gun elevation, each relative to a reference position.

5.1.9.1 SIMNET Implementation. The current SIMNET implementation expresses the azimuth and elevation angles as 32-bit integers of the binary angle measure (BAM). The information is updated with the transmission of each Vehicle Appearance PDU.

5.1.9.2 The Articulated Parts Subgroup. The Interface & Time/Mission Critical Subgroups that met in July 1990 (see Appendix C2) recommended the formation of an Articulated Parts Subgroup to investigate problems associated with the Articulated Parts Record specified in the June 1990 draft standard. This group met via teleconference and submitted a recommendation to IST for inclusion in the January 1991 draft standard. This recommendation specified articulation parameters (such as azimuth, extension, or slew rate) as primitives. The Articulation Parameters Record (see Section 5.3.3 and Annex A in the standard) allows a variable number of parameters for any number of articulated parts.

5.1.9.3 Recommendation from the Fourth Workshop. Examination of articulated parts continued at the Fourth Workshop. Since the original design of the Articulated Parts Record and PDU assumed that entity information would be issued in the form of two separate PDUs, the issue needed to be reconsidered for the single Entity State PDU case. A new format for articulated parts was recommended; this format based position on a series of articulation parameters rather than on the various parts.

5.1.9.4 Recommendation for the Standard. The recommendation for the standard is that the orientation of articulated parts be transmitted with each Entity State PDU. Representation of articulated parts is specified in the Articulation Parameter Record and is described in detail in Section 5.3.3 and Annex A in the standard.

5.1.10 A PDU for Representing Entity Information. To represent information related to an entity's appearances as well as some of its state information (location, velocity, acceleration, orientation, and so forth), a PDU is recommended to communicate all of the necessary information. This PDU is the Entity State PDU.

5.1.10.1 SIMNET Implementation. Entity Information is communicated in SIMNET through the Vehicle Appearance PDU (VA PDU). In the VA PDU, each vehicle is classified according to how many articulated parts it has and what algorithm should be used to dead reckon its appearance. The appearance field of the VA PDU is used to describe the state of any dynamic attributes specific to the vehicle. For more information on SIMNET's VA PDU, see BBN Report No. 7102 Section 7.3.3.

5.1.10.2 Position Papers Concerning the SIMNET VA PDU. The SIMNET VA PDU served as a starting point for expressing information about entities. As the VA PDU was examined for use as part of the standard, several position papers were submitted recommending changes or additions to the PDU in order to promote interoperability.

5.1.10.2.1 Position Paper [1]. This position paper recommends removing the non-dynamic information from the VA PDU in order to reduce network traffic.

5.1.10.2.2 Position Paper [10]. This position paper recommends replacing the Stationary field with a Stationary flag in the Vehicle Appearance field. This paper also recommends removing static information, as well as increasing the size of the Vehicle Appearance field to allow for a more detailed description of the vehicles.

5.1.10.2.3 Position Paper [45]. Position Paper [45] presents a proposed PDU format for placing general information that applies to all participants in the exercise first, and placing specific information depending on the vehicle category last. This paper was reviewed at later subgroup meetings, and it was agreed that the general information should come first in the structure of the PDU if the suggestion to separate the PDU into two parts is not accepted.

5.1.10.2.4 Position Paper [46]. Position Paper [47] makes three recommendations concerning the Vehicle Appearance PDU:

a. The first recommendation suggests an extension to the SIMNET Vehicle Appearance PDU. This extension would assume that the details of each vehicle's appearance can be extracted from a database at each simulator's node on the network. To minimize the volume of data required for describing the appearance, indices to standard appearance databases would be used.

b. The second recommendation proposes three additional vehicle classes: ship, aircraft, and environmental. The ship class includes surface ships, submarines, and torpedoes. The aircraft class includes fixed wing, rotary wing, and missiles. The environmental class includes such things as precipitation, smoke, chaff, and icebergs.

c. The third recommendation proposes that the Vehicle Appearance PDU should carry sensor information in the Vehicle Class element. This information would include the number of emitters and the type of emitters and would be used as an index to a sensor database that contains all relevant information about that sensor type.

5.1.10.3 BFIT Program and Recommendations. The Battle Force Import Training (BFIT) Program performed a Proof of Principle exercise in conjunction with SIMNET to address problems associated with SIMNET and non-SIMNET systems networking. The Naval Ocean Systems Center's (NOSC) report titled "BFIT/SIMNET Proof of Principle Phase I, Navy ASUW/STRIKE/AAW Protocols," January 16, 1990, recommends these enhancements to the VA PDU for Navy implementation:

a. The first recommendation is to expand the vehicle class to accommodate the additional Navy vehicles. Two new classes would include ships and aircraft. They also recommended changing the name of the vehicle class field to a vehicle type field because of the Navy meaning of "Class".

b. The second recommendation is to change the gun elevation field to an array that would indicate the number of guns, and have each gun elevation defined in the array.

5.1.10.4 Recommendations from the January 1990 Workshop. The Interface Subgroup classified the different types of vehicles into the categories of land, sea, and air. The subgroup then defined the types of information that should be included for vehicles in those specific categories. No formal recommendations were made for determining a more efficient way to organize the appearance field of this PDU. The subgroup did agree that the more general information should be placed in the beginning of the PDU, with specific appearance data following.

5.1.10.5 Recommendations from the August 1990 Workshop. The June 1990 draft standard specifies the use of an Entity Appearance PDU (now called the Entity State PDU) to represent Entity Information in a DIS. In response to the specification, several recommendations were made concerning fields of the Entity State PDU:

a. A field should be added to the Entity State PDU specifying the dead reckoning class being used to extrapolate the position of the entity that issued the PDU.

b. The Articulated Parts representation needs work. A subgroup was appointed to work on the problem.

c. Muzzle flashes should not be represented using bits in the Appearance field of the Entity State PDU.

d. World coordinates, linear velocity, and linear acceleration are to be represented using floating point numbers.

One issue discussed briefly but not resolved is whether static information should be separated from the dynamic information and issued in a separate PDU.

5.1.10.6 Position Papers in Response to the June 1990 Draft Standard and the August 1990 Workshop. Several position papers were submitted concerning entity information.

5.1.10.6.1 Position Paper [66]. This position paper examines the effect that using two PDUs for entity information (one for static information and the other for dynamic information) might have on network traffic. It assumes that static information need be sent only occasionally, but dynamic information must be sent more frequently. By sending static information less frequently than the dynamic information, less data is being transmitted at a time. The June 1990 draft standard proposes one PDU which contains both static and dynamic information that would be sent at the rate that the dynamic information is required. This position paper recommends the use of two PDUs: a Static Appearance PDU and a Dynamic Appearance PDU.

5.1.10.6.2 Position Paper [68]. This position paper was written in response to Position Paper [65]. The paper points out that introducing another PDU would complicate the protocol. It also complicates the filtering process required by simulators to determine if a PDU is of interest. A scheme which includes the static information on a periodic basis is recommended.

5.1.10.6.3 Position Paper [69]. This position paper examines the expendability of the DIS protocol as presented in the June 1990 draft standard. The paper recommends that the version number of the DIS protocol be included in the PDU header. The paper also recommends that a certain number of PDU kind numbers be reserved for official use and some for experimental use.

5.1.10.7 Recommendation for the Standard. The recommendation for the standard is for an Entity State PDU to be used to describe the appearance of each entity in an exercise. This PDU will include both static and dynamic information. This PDU will also contain a field similar to the appearance field defined in SIMNET, which will contain information on the status of the entity's dynamic attributes. This PDU is described in detail in Section 4.4.2.1.3, 4.4.2.1.4 and 5.4.3.1 of the standard.

5.2 Entity Interaction. During an exercise, DIS entities interact with each other in a variety of ways. They can fire at one another, request logistic support services, request faster update rates, collide, or emit electromagnetic or acoustic energy that may be detected by another entity.

5.2.1 Weapons Fire. The simulation of weapons fire requires the representation of a chain of events that must be communicated to other simulated entities. When a weapon is fired, the appearance of the firing entity changes so that it flashes or smokes. The path of the munition must be modeled. This modeling depends on the type of munition fired. The location of the detonation of the munition must be communicated so each entity can assess its damage. Finally, damaged entities display damage resulting from the detonation.

5.2.1.1 Appearance of Firing Entity. The first effect of weapons fire is a change in the appearance of the firing vehicle. In some cases it may be possible to see a muzzle flash or a smoking gun barrel. To represent this effect in the simulation, the firing entity transmits information so other simulated entities may correctly portray the firing entity.

5.2.1.2 Representation of Guided and Non-guided Munitions. During the Fourth Workshop in March 1991, the distinction of guided vs. non-guided was changed to munitions for which in-flight data is required vs. munitions for which in-flight data is not required. The example of the Scud missile (which is not guided but in-flight data is required) was used to substantiate this distinction.

5.2.1.3 Detonation of Munitions for Which In-flight Data is NOT Required. For these types of munitions, the firing simulator determines the trajectory of the munition and communicates the location at which the munition detonates and certain information about the detonation. In the case where the affected entity ID is known to the firing entity, the ID of the affected entity is also communicated along with the location of the detonation in terms of the coordinates of the affected entity. Each entity notes the location of the detonation and whether it has been indicated by the firing entity as having been affected. Each then assesses its own damage, communicating a change in appearance where appropriate.

5.2.1.4 Detonation of Munitions for Which In-flight Data is Required. These munitions represent munitions which can be tracked. For these munitions, the firing simulator models the trajectory of the munition. The munition is represented as a new entity. The firing simulator transmits Entity State PDUs for the munition, thus allowing simulators that are appropriately equipped to represent the sensory appearance of the munition. The firing simulator determines location of detonation or impact and transmits this information to other entities, enabling them to assess damage. If the entity ID of any affected entity is known to the firing entity, its ID is also communicated. As with munitions for which in-flight data is not required, any change of appearance resulting from the munition detonation is communicated.

5.2.1.5 SIMNET Implementation. The SIMNET protocols simulate weapons fire using a series of PDUs. A Fire PDU is issued by the firing simulator when a shell or missile is fired. When the projectile detonates, an Impact PDU or an Indirect Fire PDU is issued. If the firing simulator determines which vehicles have been struck, it issues an Impact PDU, identifying any vehicle that is struck and the location of the projectile's impact. If the firing simulator does not determine which vehicles have been struck, it issues an Indirect Fire PDU identifying only the location of impact. Each simulator then computes its own vehicle's distance from the detonation and assesses any damage. See BBN Report No. 7102, Section 7.3.4 for more details.

5.2.1.6 Recommendation for the Standard. The recommendation for the standard is for weapons fire to be simulated using the Fire PDU and the Detonation PDU. These PDUs are described in detail in Sections 4.4.3 and 5.4.4.1 of the standard.

5.2.2 Update Rate Control.

5.2.2.1 Dead Reckoning. A method of estimation called dead reckoning is employed in a DIS to limit the rate at which Entity State PDUs (ES PDUs) are issued. Since the position/orientation of entities can be estimated, it is not necessary for an entity to receive a report about every change in position/orientation that occurs in the entities it is dead reckoning. Only when a change in position/orientation differs a certain amount from the dead reckoned position/orientation is a new update required.

5.2.2.2 Threshold Values. The Threshold Value is the difference between the actual position/orientation and the dead reckoned position/orientation that triggers the issue of an ES PDU. The smaller or tighter the threshold value, the more often a host computer is likely to issue an ES PDU. Threshold values in relation to the ES PDU are based on the distance that an entity's dead reckoned position varies from its actual position, or the angle the entity's dead reckoned orientation varies from its actual orientation. Position thresholds are in the x, y and z directions. Orientation thresholds are angles about each of the entity's three axes of rotation. The initial threshold values shall be established at the start of the DIS exercise.

5.2.2.3 Dynamic Control of Threshold Values. The frequency with which one simulated platform must transmit an update of its location and orientation to another platform depends on what task the operator of the simulator is attempting to execute. It may be desirable for entities to be able to request more frequent updates from other entities. Current SIMNET protocol does not provide a mechanism to control the rate at which Entity State PDUs are issued.

5.2.2.4 Position Papers.

5.2.2.4.1 Position Paper [43]. This position paper recommends three implementations for dynamic control of error criteria:

a. The first method is local error control where each application sets its own error criteria based on the fidelity needed for its specific role, rather than being specified by the protocol.

b. The second method discussed involves remote application control of error criteria. This method allows a simulator to request more frequent updates from other simulators. New PDUs could be created for the requesting and canceling of faster updates from a specific vehicle. This could simply be an aggregation of predefined levels of fidelity. Vehicles that are not equipped to handle this PDU would simply ignore it.

c. The third method discussed involves network managing of the error criteria. The network manager would monitor network traffic and dictate the error criteria of each type of vehicle on the network.

5.2.2.4.2 Position Paper [2]. This position paper points out that higher fidelity simulators perform tasks that require a lower error threshold for updates. Typical exercises that update rate affects are air-to-air refueling, air-to-air combat, and coordinated air attacks. If the state update rate between devices is inadequate, the ability to perform these exercises will be significantly impaired or perhaps impossible to perform in a team training setting. This paper indicates several areas that still need to be addressed, such as the determination of update requirements for specific tasks, the determination of task and mission bandwidth requirements, and the impact on the update rate of interacting low and high bandwidth networks via intelligent gateways.

5.2.2.4.3 Position Paper [4]. This position paper identifies the need for the tri-services to organize an effort that will govern the classification of devices relative to functional fidelity and to provide and maintain a database listing of which devices can be faithfully operated together for different levels of network-supported training.

5.2.2.4.4 Other Position Papers. Position Paper [53] recommends that the meaning and use of the Update Threshold PDUs (as defined in the June 1990 draft standard) be further defined. Position Paper [70] cautions against the addition of performance enhancements to the standard before current protocol has been used and proven to require the enhancements.

5.2.2.5 History of Update Rate Control.

5.2.2.5.1 Time/Mission Critical Subgroup: March 1990. It was recommended that a Fidelity Request PDU and a Fidelity Response PDU be implemented to handle control of the update rate. This PDU would allow an entity to request an increased update rate from another entity by requesting that an entity change its threshold values.

5.2.2.5.2 Early Standard Implementation. The Update Threshold Request and Update Threshold Response PDUs were included in the June 1990 draft standard. The text and explanation were further refined in the January 1991 version with the inclusion of state diagrams.

5.2.2.5.3 Fourth Workshop. In March 1991 at the Fourth Workshop, further work on update threshold was done. Position Paper [78] was presented with a recommendation to revise the state representations of update threshold control. The Interface & Time/Mission Critical

Subgroup recommended that Update Threshold Control NOT be a requirement in the standard, but be made optional (removed from Sections 4 & 5 and moved to Section 6 of the standard (IST-PD-91-01) with the Emitter and Radar PDUs). In support of the Update Threshold Control PDUs, the Performance Measures Working Group recommended that the PDUs remain as a required part of the draft standard.

5.2.2.5.4 Fifth Workshop and Steering Committee Decision. The steering committee determined that Update Threshold Control be moved to Section 6 of the standard (IST-PD-91-01) and not be required in the draft standard. During the Fifth Workshop, held in September 1991, there was some informal discussion about excluding Update Threshold Control from the document completely. This recommendation was confirmed by the steering committee and is reflected in the October 1991 revision of the draft standard.

5.2.2.6 Recommendation for the Standard. The recommendation for the standard is that the control of the rate at which PDUs are sent be deleted from the draft standard.

5.2.3 Logistic Support. To realistically represent an actual battle situation, simulation of repair and resupply of vehicles is desirable for the simulation exercise.

5.2.3.1 Repairs. A platform type entity may occasionally need repair due to normal wear and tear or battle damage. When a repair is needed, the protocol must provide several messages that can be communicated:

a. Request for Repair. The entity needing repair must be able to communicate this need to another entity that may be able to provide the service.

b. Repair. If a repair can be made, a mechanism is required that would allow for the repair to take place. This mechanism would consist of allowing a period of time to pass in which the repair would be made. No message is required for this function.

c. Repair Completion. When the repair is completed, the entity providing the repair must be able to communicate what repair has been made.

d. Repair Cancel. If it is not possible to complete a repair after it has been initiated, a means to cancel the repair is required.

5.2.3.1.1 SIMNET Implementation. The SIMNET protocol provides the functions required for the repair of a vehicle type entity. In SIMNET protocol, the vehicle requiring the service, or the "receiver", queries a potential provider or "supplier" for repairs. If the identified "supplier" is within an appropriate distance and both vehicles are stationary with neither having been destroyed, conditions are appropriate for a repair to take place. The supplier provides the repair and informs the receiver of the repair performed. Further details on SIMNET's implementation of repairs are found in BBN document No. 7102, Section 7.3.7.

5.2.3.1.2 Recommendation for the Standard. The recommendation for the standard is that a repair function be implemented through the use of a series of PDUs in a manner similar to that of SIMNET. These PDUs and their use are described in detail in Section 4.4.4.3, 4.4.4.9-4.4.4.12 and 5.4.4.2 of the standard.

5.2.3.2 Resupply. An entity may occasionally require additional supplies such as munitions, food, and medical supplies. When this is the case, a mechanism must be provided whereby an entity can be resupplied. When a resupply is required, the protocol must provide several messages that can be communicated:

a. Resupply Request. The entity that needs supplies must be able to communicate this need to another entity that may be able to provide the service.

b. Response to Request for Resupply. Once a request has been received, the responding entity must be able to communicate whether or not it is able to respond. In its response, the entity indicates what supplies it can provide and in what amounts.

c. Resupply. If a resupply can be made, a mechanism is required that would allow for the resupply to take place. The entity receiving supplies must be able to communicate how much of the offered supplies have been taken.

d. Resupply Cancel. If it is not possible to complete a resupply after it has been initiated, a means to cancel the resupply is required. Should a resupply function be canceled, no supplies are transferred for the transaction that was in progress when the cancel occurred.

5.2.3.2.1 SIMNET Implementation. The SIMNET protocols provide functions such as these described above for the resupply of a vehicle. (For more details on SIMNET's resupply functions, please refer to BBN Report No. 7102 Section 7.3.6.).

5.2.3.2.2 Recommendation for the Standard. The recommendation for the standard is that a resupply function be implemented through the use of a series of PDUs in a manner similar to SIMNET. These PDUs and their use are described in detail in Section 4.4.4.2, 4.4.4.4-4.4.4.8 and 5.4.4.2 of the standard.

5.2.4 Collisions. When a collision occurs between simulated entities, the collision must be reported so that the entities involved are all aware of the collision and are able to assess any resulting damage. Included in this collision report is information indicating which entities are involved and information about the force of the impact.

5.2.4.1 SIMNET Implementation. The SIMNET protocols use a Collision PDU to report collisions between entities. This PDU serves two purposes: it ensures that when entities collide each is aware of the collision, and it allows the cause of entity damage to be identified.

There are two ways in which the Collision PDU is used:

a. When any simulator becomes aware of a collision between its entity and another entity simulated elsewhere, it issues a Collision PDU.

b. When a single simulator detects a collision between two entities that it is simulating, it reports the event by issuing a Collision PDU.

The contents of a Collision PDU include the identification of the issuing entity and that of the target entity.

5.2.4.2 Other Observations. Upon examination of the Collision PDU of the June 1990 draft standard, it was determined that it would be desirable to provide more detailed information about the collision in order to better assess resulting damage. The recommendation for the standard is that information such as the mass, velocity, and location of impact in entity coordinates be provided in the Collision PDU.

5.2.4.3 Fourth Workshop Recommendation. Position Paper [78], presented at the March 1991 workshop, recommended that the draft standard specify that both entities involved in a collision be required to issue a Collision PDU. The Interface & Time/Mission Critical Subgroup voted to accept the recommendation.

5.2.4.4 Recommendations for the Standard. The recommendation for the standard is that collisions that occur in a simulation exercise be communicated by the issue of a Collision PDU. This PDU is to be issued by all entities involved in a collision. This PDU is to include the additional information recommended in paragraph 5.2.4.2. This PDU and its use is described in detail in Sections 4.4.5 and 5.4.4.3 of the standard.

5.2.5 Electronic Interaction. The development of technology in the area of sensory data has produced a variety of sensors and emitters ranging from the sonar of ships to the tracking radar of aircraft. Representation of these devices is essential for a simulation exercise.

In a simulation, an entity must communicate the presence of an emitter when it is activated. For example, if a radar is activated or deactivated, an entity with a detector must be informed of the event if its detector is on.

5.2.5.1 <u>SIMNET Implementation</u>. In the SIMNET protocols, a Radiate PDU is issued by the simulator for any vehicle possessing radar capability. The Radiate PDU reports the type of radar and the set of target vehicles illumined, and identifies the subset of those targets that were actually detected by the radar. The PDU also includes the radar location and a description of certain characteristics of its signal.

5.2.5.2 <u>Position Papers</u>. Several position papers address issues concerning the use of Electronic Warfare (EW) equipment and its representation in a simulation exercise.

5.2.5.2.1 <u>Position Paper [36]</u>. This position paper discusses thetraining benefits of and the requirements for High to Medium altitude Air Defense (HIMAD) weapons systems. The paper recommends that the standard protocol support the multi-function phased array radar of the PATRIOT missile as well as the HAWK. Two PDUs are recommended: one to report Electronic Counter-measures (ECM), such as jamming, along with its characteristics, and another to report Identify Friend/Foe (IFF) actions with their parameters.

5.2.5.2.2 <u>Position Paper [46]</u>. This position paper proposes a protocol that can support new warfare areas such as Anti-Submarine Warfare (ASW), Anti-Air Warfare (AAW), and Electronic Warfare (EW). To accommodate sensory information such as parametric descriptions of acoustic signatures, parametric descriptions of active sonar emissions, and descriptions of radar returns, this position paper recommends that this information be included in each simulator's database. Descriptions of voluntary emissions should also be included as part of the Entity State PDU. Other emitter information recommended for the Entity State PDU includes: number of emitters, emitter type, emitter name, emitter mode, emitter location, and emitter status.

5.2.5.2.3 <u>Position Paper [47]</u>. This position paper discusses advanced notification when a track (simulated object) is to maneuver. A problem is encountered by the existence of different radar devices. Fire Control Radar, Search Radar, and Phased Array Radar each require different update rates. Extrapolation between updates could lead to inaccurate radar representations of the track being radiated. Also, if a target is being tracked by two different sensors, each having a different update rate, the position of the target may not correlate. The paper recommends that target maneuvers be done with advance notification in all cases.

5.2.5.2.4 Position Paper [48]. This position paper discusses the advance notification to targets that they are being radiated. Considering the numerous types of radar (search radar, fire control radar, illuminators, lasers, and sonars) a target may be illumined by emitters of several platforms simultaneously. There is also a need to provide parametric data concerning the emitter. This data may include: power level, Pulse Repetition Frequency (PRF), frequency, polarization, and waveform. This information may exist in a database or may be included in data link messages to the track. The paper recommends that tracks be notified when being radiated by Fire Control Radar, Continuous Wave Illuminations (CWI), or Sonar. Further study is recommended to determine how parametric information is to be conveyed.

5.2.5.3 Discussion of Alternatives. Just as the Entity State PDU describes the state of an entity based on reflected light, an Emitter PDU would describe the appearance of an entity in terms of its emissions in the acoustic and electromagnetic spectrum. Consequently, the Emitter PDU should function in a manner very similar to the Entity State PDU.

There are two ways in which this information might be distributed in a simulation exercise:

a. Information concerning the types of emitters as well as all operating parameters is distributed to other entities when an entity emits.

b. Each entity is required to keep a table concerning the capabilities of certain types of emitters. Information concerning just the types of emitters and their modes is communicated and the receiving host derives the operating parameters from the table.

Modern emitters are quite sophisticated and have so many modes that transmitting the parameter information would quickly overwhelm the network. In addition, this parameter information is highly classified and would be more easily protected by maintaining it in table form stored in a host computer. The military is developing emitter databases for use in simulators (for example, UTSS) and in target recognition algorithms. By using these databases in host computers, DIS will be capable of simulating the operation and detection of a large number of emitters without overloading the network. In addition, intelligence updates could be incorporated by changing values in the tables instead of modifying simulation algorithms.

One problem with the database approach is that it could require host computers to maintain a large database for entities with few sensors. To prevent this problem, the recommendation for the standard is that the Emitter PDU contain a field that indicates the portion of the acoustic or electromagnetic spectrum in which this emitter operates (see Table II, Appendix F in the standard (IST-PD-91-01)). This field will allow a host computer or intelligent gateway to ignore any PDU that addresses emissions in a range not detectable by the simulated entity.

Position Paper [48] recommends advance notification of emitter operations. This advance notice concept pre-supposes a scenario controlled exercise. DIS is intended for a free-play environment and no advance notification would be possible.

Since the Emitter PDU represents the acoustic or electromagnetic appearance of the entity, the location and operating parameters should be transmitted often enough to allow the receiving entities to maintain an accurate representation of emitter location and mode through dead reckoning. One option is for an entity to transmit an Emitter PDU every time it transmits an Entity State PDU. However, the resolution of acoustic and electromagnetic sensors is generally different from direct vision. Therefore, the recommendation for the standard is that a separate dead reckoning algorithm be used for the Emitter PDU from the one used for the Entity State PDU.

5.2.5.4 Position Paper [56]: In Response to the June 1990 Draft Standard. This position paper points out that the approach of the Emitter PDU is a suitable one, but as long as the database it depends on does not exist, some interim solution is needed to provide for current needs. The paper recommends the use of a Radar PDU until the Emitter PDU is ready for use.

5.2.5.4.1 Position Papers [74] and [94]. Position Paper [74] discussed the requirements for representation of ASW simulations. Part of the requirement includes support for various acoustic and ocean characteristic representations. Other acoustic and ocean characteristics are discussed in Position Paper [94].

5.2.5.4.2 Fifth Workshop and the Work of the Emitter Subgroup. The Emitter group (a subgroup of the Interface & Time/Mission Critical Subgroup) began working on the problem of electromagnetic and acoustic emissions during the summer of 1991. At the Fifth Workshop, the group continued its work, making several proposals for the Radar, Emitter, and a new Ocean PDU. These recommendations will be implemented in the Final Draft of Version 1.0 of the draft standard (IST-PD-91-01).

5.2.5.5 Recommendations for the Standard. The recommendation for the standard is that the Radar PDU be used as an option for representation of radar emissions until the Emission group develops a recommendation for the Final Draft of Version 1.0 of the draft standard (IST-PD-91-01). The Emitter PDU is also included as an optional representation for emissions. The Emitter PDU is described in detail in Section 6.3.2 of the standard (IST-PD-91-01). The Radar PDU is described in Section 6.3.3 of the standard (IST-PD-91-01).

5.2.6 Radio Communication. For a realistic battle environment, the capability of radio communication of both data and voice is very much needed. The radio communication should provide the capability to transmit an actual voice or a reference to a pre-recorded database in real-time over a network.

5.2.6.1 Fifth Workshop Work on Radio Communication. In this workshop, Mr. Richard Schaffer and Mr. John Burnett presented the concept of Radio Communication as a requirement for DIS. As a result, the Interface & Time/Mission Critical subgroup created the Radio Communication subgroup to a create the appropriate PDUs to support radio communication. There was no formal paper submitted to the this workshop for release.

5.2.6.2 Sixth and Seventh Workshop Work on Radio Communication. As result of the sixth workshop, three radio communication PDUs were created: Transmitter, Signal and Receiver. These three PDU were further refined at the June/92 interim meeting and they were included in the DIS PDU Draft Standard Version 2.0 (IST-CR-92-12) released at the Seventh workshop for review and comment.

5.3 DIS Management.

Centralized control of a simulation is necessary in order to manage the operation of the network hardware and to manage certain aspects of the simulation exercise. DIS management functions can be divided into three categories: Network Management, Simulation Management, and Performance Measures. These three functions are described in detail below.

5.3.1 Network Management.

5.3.1.1 Advantages of Network Management. A network may consist of devices such as hosts, gateways, and terminal servers. Management of such devices, called network elements, has several advantages:

a. It minimizes the time and complexity of maintaining network elements.

b. It allows for fullest use of network resources.

c. It allows for expansion of the network to include other network elements, even after initial implementation.

5.3.1.2 Functions of a Network Manager. A network management node may exist for each Local Area Network (LAN) on a Wide Area Network (WAN). Functions performed in managing a network include:

a. Administration

- Collection and analysis of information
- Trend analysis & utilization reporting

b. Monitoring

- Real-time view of network status
- Quick response to outages
- Audit trail provided when possible

c. Control

- Prevention of network outages by pre-emptive measures
- Response to problems by isolation of offending device

As the size of a DIS grows, the amount of network management required may increase.

5.3.1.3 Recommendations for the Standard. Further study is recommended to identify a Network Management protocol appropriate for DIS Management. This topic is being examined by the CASS group and the final recommendation will be included as part of the CASS standard. No other recommendations are made for this standard.

5.3.1.4 Further Research. A possible candidate for further research in Network Management protocol is the Simple Network Management Protocol (SNMP) as recommended in Position Paper [44].

5.3.2 Simulation Management. As the complexity and size of a simulation increases, it makes more sense for some functions of the simulation to be performed by a central node rather than by individual hosts. Simulation management is important for the establishment, maintenance, and termination of a simulation exercise. How this function may be accomplished has not yet been established.

Simulation Management should include the following functions:

- Exercise setup
- Exercise start/stop/restart
- Exercise maintenance
- Exercise end

5.3.2.1 SIMNET Implementation. SIMNET uses the Master Command and Control System (MCC) to set up an exercise and introduce entities to the start of a simulation. The MCC is not a manager, but exists as a peer entity with special abilities. Vehicles can be introduced into a simulation exercise using Activate Request/Response PDUs. Similarly, they can be withdrawn from the exercise using Deactivate Request/Response. See BBN Report No. 7102 Sections 7.3.1 and 7.3.2 for more details.

5.3.2.2 Recommendations for the Standard. Since management functions have not been closely examined by the simulation community, no recommendation concerning a management function is made for this standard. As an interim solution, the recommendation for the standard is that an activate and deactivate function be provided to introduce entities into a simulation exercise. These functions are implemented through the issue of Activate Request/Response PDUs and Deactivate Request/Response PDUs as is done in SIMNET protocol. Details concerning the above mentioned PDUs are found in Section 6.3.1 of the standard. When a Simulation Management function is implemented it will supersede this interim solution.

5.3.2.3 Position Papers on Simulation Management. Two possible candidates for Simulation Management were presented during the Fifth Workshop in September 1991. SIMAN is detailed in Position Paper [88] and proposes a protocol to handle many simulation management functions. Position Paper [98] discusses techniques for initialization and restart of a simulation exercise.

5.3.2.4 Fifth Workshop Work on Simulation Management. The Interface & Time/Mission Critical Subgroup formed a smaller group to address the issues of initialization and simulation management. This group is working with the Performance Measures group to develop recommendations for various functions and PDUs required for Simulation Management. The recommendations of this group will be included as part of Revision 1 of the draft standard (IST-PD-91-01).

5.3.2.5 Sixth Workshop Work on Simulation Management. Position paper [124] was presented to the Simulation Management subgroup proposing the necessary simulation management PDUs to meet the requirements established by the Exercise Control and Feedback Requirements subgroup. These PDUs were revisited at the June/92 interim meeting and included in the DIS PDU Standard Version 2.0 (IST-CR-92-12) released at the 7th workshop.

5.3.2.6 Seventh Workshop Work on Simulation Management. The 12 simulation management PDUs included in the DIS PDU Standard Version 2.0 (IST-CR-92-12) are: Create Entity, Remove Entity, Start/Resume, Stop/Freeze, Acknowledge, Action Request, Action Response, Data Query, Set Data, Data, Event and Message. These 12 simulation management PDUs were presented to the ITMC subgroup members for review and comments.

5.3.3 Performance Measures. There are two aspects to performance measures: operator performance measures and equipment performance measures. Each of these topics is discussed below.

5.3.3.1 Operator Performance Measures. The purpose of operator performance measures is to allow the capture of operator actions that do not result in an externally observable action and are not normally transmitted between entities. Under some conditions, the network will not be heavily loaded and the central evaluator will send a command stating that all operator performance measures are to be transmitted during the exercise. Under other conditions with a large number of entities on the network, the central evaluator will send a command to store operator performance measures and to transmit these measures after the end of the exercise.

5.3.3.2 Equipment Performance Measures. The intent of the Equipment Performance Measures is to allow the capture of equipment mode changes and intermediate steps in equipment operation not normally transmitted outside the host computer. As discussed above for Operator Performance Measures, commands to store or transmit these measures will come from a central evaluator node.

5.3.3.3 Working Group Recommendations. For the Third Workshop 1990, a Performance Measures Working Group was formed. This group discussed various issues concerning performance measures and recommended several PDUs to provide the required performance information. For more details on the Performance Measures Working Group recommendations, see the Summary Report: The Third Workshop on Standards for the Interoperability of Defense Simulations, Vol. I, pp. 156-166.

5.3.3.3.1 Performance Measures Query PDU. This PDU would allow the exercise controller or evaluator to request system or trainee performance measures not normally transmitted over the network. For example, when a passive sensor system (such as infrared) changes modes, there is no observable event and nothing is transmitted over the network. This approach assumes that the evaluator has previously developed a table of measures for storage in the various simulations. This table would assign a number to each measure. For example, fire control system mode may be measure #14 and radar altimeter reading may be measure #27. The Performance Measures Request PDU would contain the following information:

a. The address of the evaluator requesting the performance measures.

b. The addresses of the entities requested to provide the performance measures.

c. The phase of the exercise in which these performance measures are to be transmitted.

d. The number of performance measures requested in this PDU.

e. The number of the first performance measure requested.

f. The requested transmittal rate of the performance measure in cycles per second.

g. The same information for the remaining performance measures requested.

5.3.3.3.2 Performance Measures Response PDU. If the simulation receiving this performance measures request PDU is able to provide the requested measures, the data will be contained in a Performance Measures Response PDU. The contents of this PDU will be:

a. The address of the evaluator requesting the performance measures.

b. The address of the entity providing the performance measures.

c. A time stamp indicating when these performance measures were captured.

d. The number of performance measures contained in this PDU.

e. The number of the first performance measure provided.

f. The performance measure value.

g. The same information for the remaining performance measures provided.

5.3.3.3.3 Information Query PDU. There are times when an evaluator needs to know the value of a given group of variables. The Information Query PDU will provide this information. The contents of this PDU would be:

a. The address of the evaluator requesting the performance measures.

b. The addresses of the entities requested to provide the performance measures.

c. The number of performance measures requested in this PDU.

d. The numbers of the performance measure requested.

5.3.3.3.4 Performance Measures Standard. The Performance Measures Working group has begun development of its own standard document. Further recommendations in the area of performance measures will be included in that standard and not in this draft standard. It is also useful to note that as of the Fifth Workshop, the Performance Measures group has changed its name to the Fidelity, Exercise Control, and Feedback Requirements Group (FECFR).

5.3.3.4 Recommendation for the Standard. The recommendation for the FECFR standard is that further study be performed in defining PDUs that will allow a central evaluator to query for pre-defined operator and equipment performance measures and for the simulators to respond with the appropriate information. No recommendations concerning Performance Measures are made for the standard that this Rationale Document addresses.

5.4 Environment Information

For simulated entities to participate in the same exercise, they must have access to the same environment information. Different types of information about the environment are necessary in order to make the exercise as realistic as possible. This information may include changes in the terrain, weather, and ambient illumination.

5.4.1 Dynamic Terrain and Cultural Features.

5.4.1.1 Description. During the course of a real battle, changes in the terrain occur frequently. An explosion may create a crater or blow up a bridge. Ditches might be dug and defensive embankments might be built. In addition, cultural features such as bridges and buildings could be destroyed or built. All of this information must be available to the participants in a simulated battle just as it would be accessible in a real battle. In available DIS implementations, this feature is not included. Future implementations must provide the necessary functions to support dynamic terrain and cultural features.

5.4.1.2 SIMNET Implementation. Currently, SIMNET protocol does not support the functions associated with dynamic terrain and cultural features. SIMNET protocol does provide a means by which entities can join an exercise that is already in progress. This function is accomplished using a protocol data unit called the Activate PDU. Since changes in the terrain and cultural features are not supported, there is no need to update entities that join an exercise after the initial start time. Identification of environmental objects is also not needed. See BBN Report No. 7102 Section 7.3.1 on Vehicle Activation for more information concerning the Activate PDU.

5.4.1.3 <u>Position Papers</u>. Two concerns have been expressed in position papers:

a. How should entities that join the exercise after the initial start time be informed about changes in the terrain?

b. Is there a method that would allow identification of environmental objects?

Several position papers addressed the issues associated with dynamic terrain and cultural features.

5.4.1.3.1 <u>Position Paper [1]</u>. This position paper briefly presents the problem of communicating changes in the terrain database to vehicles entering the simulation after an exercise has begun. No recommendations were made.

5.4.1.3.2 <u>Position Paper [6]</u>. This position paper considers Dynamic Environment issues. These issues include:

a. Updating late players on changes in the data base related to environmental effects, destructive effects, and engineering effects.

b. Determining methods for identification of environmental objects.

Recommendations made in this paper include:

a. Implement a common database on the network to keep track of dynamic changes. Each network node would access this database in order to calculate its visual, sensor, and feature correlation, and weather data. A problem with this method is that it would require very high network bandwidth.

b. Require each system to announce its own modifications by broadcasting each time it makes a change to the database. A problem with this recommendation is that each simulator would have to keep a record of all modifications in order to retransmit information any time a new player joins the simulation.

c. Provide a database management node whose job is to manage the database activities. The node would record all changes and update new players as they enter the battle.

5.4.1.3.3 <u>Position Paper [9]</u>. This position paper discusses the issue of data manipulation. Data manipulation includes the ability to use database information but would also allow changes to be made to the database. This would allow modeling of the effects of external forces on the terrain or changes in the environment caused by weather, seasons, and engineering actions.

5.4.1.4 Recommendations for the Standard. Since Environment Information is not within the scope of the standard, no recommendation concerning dynamic terrain is made. As an interim solution, the recommendation for the standard is that certain cultural features, such as bridges and buildings, be represented as entities. These cultural feature entities would have appearances as would any other entity participating in the simulation exercise, except their position is static. Thus, a shell could strike a bridge to destroy it. Repairs could be made in a manner similar to repairs to entities (see Section 5.2.3.1). Decisions as to which features would be defined as entities would take place prior to an exercise. Entity information concerning cultural features is found in Section 5.1.3.1.5 of this document and Appendix H1 of the standard (IST-PD-91-01). Upon adoption of a general scheme for dynamic terrain and cultural features, this interim solution would be superseded.

5.4.1.5 Further Research. A possible area for further study is the use of a method similar to that described in Position Paper [6] in recommendation number three. Some details of this recommendation are also discussed in the Section on Exercise Maintenance in Section 7.5.4.

5.4.1.6 Defensive Embankment. Current doctrine calls for plowing up mounds of dirt to serve as defensive embankments for tanks. Accomplishing this task during an exercise would require modification of the terrain database using micro-terrain. Research is underway to develop this capability.

5.4.1.6.1 Recommendation for the Standard. During the interim period before modifiable terrain databases are developed, the recommendation for the standard is that a Defensive Embankment entity be created that will be treated in a manner similar to cultural features. Tank commanders will request defensive embankments from the engineers. The evaluator for the LAN or WAN will enter a keyboard command and, after the appropriate delay, the embankment will be placed at the requested position. After emplacement, this embankment will provide visual concealment and protection from weapons appropriate for a defensive embankment.

5.4.2 Database Correlation. Correlation of database information is essential to the realism of the simulation exercise as well as to the effectiveness of the training. Without the necessary correlation, anomalies may exist that take away from the believability of the simulation. One example is the appearance of a tank floating in the air due to a lack of correlation of terrain features. Training value may be degraded if line of sight calculations differ, allowing one entity to see another when the other entity assumes it is well hidden. Other database issues include correlated information in non-terrain databases. Although some of these issues are examined elsewhere, it seems appropriate to examine them in this context as well.

5.4.2.1 Position Papers. A number of problems are associated with a lack of database correlation. These problems are discussed in various position papers. A summary of these issues is provided below.

5.4.2.1.1 Position Paper [3]. This position paper presents several issues associated with Environmental Correlation between simulators on a network. These issues include:

a. Attributes of the Navigational Facilities. This issue considers the storage of radio/navigational and communication data. This type of data should be easily accessible and usable in real time, easily updated, and quickly changed. A recommendation is made to have a copy of a common navigational facility file located on each device on the network.

b. Earth Model Definition. Inconsistencies in computed location can occur if a common earth model is not used by all entities on the network. These inconsistencies could cause problems with long distance interception and coordination between aircraft. A recommendation is made to either have the earth model defined on a central point on the network or to require all simulators to have the same earth model. The former could cause problems with latency when waiting for information exchange between simulator and central node, while the latter would require software changes by simulators.

c. Global Positioning System Satellite Coverage. Global Positioning System Satellite (GPSS) coverage is important for deep strike penetration and special operations. Four satellites are needed to provide accurate three dimensional position and coordinated universal time and velocity. The paper recommends that detailed models of GPSS coverage be used or a file should be available with satellite data to determine coverage and characteristics. The former could be taxing to resources.

d. Magnetic Variation. Knowledge of magnetic variation is important for the navigational equipment of aircraft and naval vessels. Several different methods are used to model this variation in a simulation. To provide a consistent magnetic variation in networked simulators, the paper recommends that either a general method or model be implemented at each device, or the same model could be contained on a central database on the network.

e. Man-made and Natural Environmental Effects. Many environmental effects are necessary to insure the realism of the simulation. Naturally occurring effects such as atmospheric pressure, wind, temperature, and all types of weather need to be simulated as well as smoke and fog. The paper recommends that these elements be included in the simulation.

5.4.2.1.2 Position Paper [5]. This position paper discusses the problems associated with a lack of correlation between environmental databases. Issues that are addressed include:

a. Height above terrain correlation. It is important that the terrain databases of different simulators correlate. If correlation is inadequate, vehicles may be depicted as floating in the air or burrowing into the ground. A recommendation is made to pass only the latitude and longitude (or similar coordinate data) on the network and require each simulator to calculate the altitude and orientation of the displayed visual model.
b. Crash detection. Calculation of crashes between simulators and other objects within the environmental database relies on information about objects stored within the database. If each simulator does not contain the same information to the same level of detail, low fidelity devices may not detect a crash, but a high fidelity device might detect it.

c. Line of sight, sensor, visual and automated threat databases. Line of sight calculations determine the capability of an entity to see another entity in the simulated world. A lack of correlation of objects in a database could affect the realism of a simulation. For example, it is possible that one vehicle may believe it is hidden when another vehicle can actually see it.

A recommendation to handle the above problems is to introduce only one network feature correlation device. This may involve placing one or several of the same feature correlation devices on the network. Another recommendation is to require a high degree of correlation in content and placement between all of the feature correlation devices on the network along with the visual/sensor and automated threat databases. Further investigation is needed to determine the amount of acceptable error.

5.4.2.1.3 Position Paper [9]. This position paper discusses key issues concerning terrain databases and the present SIMNET protocol. Some of these issues include:

a. Level of Detail (LOD). The LOD of terrain features may have an effect on the training value of a simulated exercise. One example is the effect the LOD of features may have on target recognition tasks performed by air defense gunners.

b. Interfaces. Problems can occur when interfacing SIMNET or other simulations to the trainee. A standard map cannot be used by the trainee if it does not match the detail of the terrain in the simulated world. Because Interim Terrain Data (ITD) comes from low resolution, inaccurate and dated Tactical Terrain Analysis Database (TTADB) sources, it does not accurately describe the real world.

c. Raster-based or polygon-based data. Data in a simulation must be represented in a manner flexible enough to be viewed in multiple ways.

d. Multiple simulator models. There must be some correlation between a simulator and how it handles a set of data. A recommended way to resolve this problem is to create a validation test to determine if a new simulator will correlate with others.

e. Data manipulation. Data manipulation involves using data within a database as well as updating it. This would allow the modeling of the effects of external forces on the terrain or changes in the environment caused by weather, seasons, and engineering actions.

5.4.2.1.4 Position Paper [34]. This position paper discusses two types of database formats presented at the January 1990 conference. These are SIMNET Database Interchange Specification (SDIS) and the Generic Transformed Database (GTDB) format. The paper addresses how changes are made and communicated in the databases. Two types of changes are presented:

a. Incremental changes, or updates. These occur when features and attributes are added to the simulated world, or anomalies are corrected. These types of changes are made off line.

b. Dynamic changes. These occur during the course of a simulation exercise and must be communicated across the network in a coherent and efficient manner.

5.4.2.2 Recommendations for the Standard. Further study of techniques to correlate database information should be performed. No other recommendations were made for this standard.

6. **DATA REPRESENTATION**

In presenting the format of the standard, certain data structures must be established. The following text contains a discussion of the data format, a summary of applicable position paper discussions, and a recommendation for use with the standard.

6.1 Number Representation

In general, the digital representation of numbers is categorized as fixed point (integer) or floating point (real). Integers may be signed or unsigned, and the most significant bit is usually designated as the sign bit, which will be 0 for positive numbers, 1 for negative. Real numbers consist of a sign bit, a mantissa field, and an exponent field. The size of the real number depends on the range or accuracy requirements of the application, but, it is usually 32 or 64 bits.

6.1.1 SIMNET Implementation. The current SIMNET system uses 8, 16, and 32-bit signed and unsigned integers, and adheres to the IEEE 754-1985 standard of data representation for floating point numbers.

6.1.2 Position Papers. Position papers have addressed the issue of non-standard number representation. Although the IEEE standard has found wide acceptance, it is not universal in its implementation. The suggestion has been made that all data be transmitted as integers in order to provide a standard basis for data exchange (see Position Paper [41]). This recommendation was also made in the subgroup meetings.

After the draft standard was first published in June 1990, Position Paper [57] was submitted recommending the use of floating point. The paper's main argument for floating point numbers is that experimentation has shown that floating point numbers are comparable to integers in processing speed given a number of different processor platforms. In fact, in some cases floating point numbers were shown to be more efficient than fixed point numbers. This position paper was presented at the July 1990 subgroup meeting and the third workshop (see Appendix C2 and D3 of the standard). Subsequent subgroup discussion led to a change in the original recommendation so that floating point numbers would be allowed in the DIS draft standard.

6.1.3 Recommendation for the Standard. The recommendation for the standard is that numbers be specified as either integer or floating point, whichever is more appropriate for their particular application. Single and double precision floating point numbers will adhere to the IEEE 754-1985 standard. Integers will be represented in two's complement form. They may be signed or unsigned and may have a size of 8, 16, or 32-bits. The most significant bit designates the sign bit. The value zero represents positive numbers and the value one represents negative numbers.

6.2 Enumeration Representation

Enumeration data types are user-defined values or identifiers which may be numeric, character, or identifier values. In a list of values, the first values in the list have lower values than the latter values in the list. For example:

```
type week_day is  (monday, tuesday, wednesday,thursday,
                  friday);
type color is     (red, orange, yellow, green, blue,
                  violet);
```

When transmitting enumerated types across a network, the position of a value in the enumeration list is transmitted. The first element of the type declaration should be zero. For example:

```
week_day'pos (monday) -- expression has value of 0
color'val (1)         -- expression has value of orange
```

6.2.1 <u>SIMNET Implementation</u>. In the current SIMNET protocol, the first element in an enumerated type list is associated with zero by default. The default value may be overridden by explicitly defining a non zero value for the first value in the list.

6.2.2 <u>Recommendation for the Standard</u>. Double and single precision enumerated types on the network should begin with zero in all cases for the first element of the type declaration.

6.3 Angle Representation

The standard must identify a means by which angular measure and its time derivatives may be described.

6.3.1 <u>SIMNET Implementation</u>. For articulated part orientation, the current SIMNET protocol uses a 32-bit binary angle measurement to describe the angle of the turret relative to the hull and the gun barrel relative to the turret. The 32-bit integer represents the fractional part of a circle, bisected successively 32 times. This is known as the binary angle measurement (BAM) method.

6.3.2 <u>Position Papers</u>. While BAMs cannot be used directly as arguments, transcendental functions are rarely calculated in real time on low-cost uniprocessor simulation hosts. A typical approach is to have a resident look-up table which can return a value in relatively few CPU cycles. BAMs provide the greatest angular precision with a given number of bits, and may be incremented without regard to multiples of 2*pi as they reset to zero upon overflow.

6.3.3 Recommendation for the Standard. Angles will be specified as 32-bit integers expressed in binary angle measurement (BAM).

6.3.4 Recommendation to the Standard as result of the IEEE balloting process. In the DIS PDU standard approval process in IEEE, many requests were received to change the angle representation from BAM to Radians. As a result of that, the ITMC group of the 7th workshop revisited the angle representation issue and decided to change it from BAM to Radian. Therefore, all the references to BAM were changes to Radians in the standard.

6.4 Octet Ordering

Although octet ordering is not within the scope of this standard, one position paper expressed a concern for an octet ordering method. An explanation and recommendation are made in the following paragraphs:

6.4.1 Definition of Octet Ordering Methods. Two commonly used methods of transmitting data serially are the so-called Big Endian and Little Endian formats. With the Big Endian format, the eight bits of each octet are transmitted on the medium in the order that would be read in a left to right fashion. The left most bit is the most significant bit (MSB) and is transmitted first. The right most bit is the least significant bit (LSB) and is transmitted last. Similarly, when a multi-octet field is transmitted, the most significant octet is transmitted first from high order to low order. With the Little Endian format, the opposite is true. The first bit (or octet) transmitted is the least significant and the last is the most significant. The decision as to which is used for a particular application depends upon the brand of equipment selected.

6.4.2 SIMNET Implementation. The current SIMNET system employs the Big Endian format, due largely to its implementation upon a VME-compatible architecture.

6.4.3 Position Papers. Concern has been raised that a larger number of equipment manufacturers adhere to the Little Endian format (see Position Paper [35]).

6.4.4 Recommendation for the Standard. The Big Endian format is specified as an Internet standard. For compatibility with this and other standardization activities (Modular Simulator System), the Big Endian format is recommended for network data ordering.

6.5 Time Stamping

Time stamping may be required for certain levels of precision, especially in cases where delays in network transmissions are unpredictable or unknown. A timestamp may be especially useful where entities move at high rates of speed or change velocity rapidly or where emissions such as electro-magnetic signals change modes rapidly.

6.5.1 SIMNET Implementation. In the SIMNET protocol, the Time data type represents a date and time as a count of the seconds elapsed since 0 GMT, 1 January 1970. This type is represented using a 32-bit unsigned integer called Time. The SIMNET protocol uses the timestamp to determine the relative timing of consecutive Vehicle Appearance PDUs describing the same vehicle. The timestamp is used in dead reckoning a vehicle's appearance by storing the timestamp of the Vehicle Appearance packet initially received, comparing the timestamp of the next Appearance packet from the same vehicle, and using the time difference to extrapolate the position of the vehicle. Time stamping is also used in association with the Data Collection PDUs to record an exercise for playback or analysis. SIMNET protocol does not employ clock synchronization (See BBN Report No. 7102, Section 3.4).

6.5.2 Position Papers. Position Paper [8] recommends a timestamp with the variables of state of each data packet. This timestamp would represent the time at which the variables are valid, and not the time at which they were computed or transmitted. The timestamp would represent the time elapsed since the beginning of the current hour. The receiving node on the network would subtract this time from the time at which the variables are to be displayed, and extrapolate over the difference.

This same position paper recommends two methods for clock synchronization. A time standard can be accessed through the National Institute of Standards and Technology (NIST) which distributes it by radio from several stations. Propagation delays can be corrected, and commercially available equipment can be used to interface the radio signal with a digital computer. Telephone services are also available with correction for propagation delays. The paper also states that a timestamp of one millisecond accuracy is achievable.

6.5.3 Subgroup Meeting. It was the unanimous decision of the Time and Mission Critical Subgroup that the time stamping method of Position Paper [8] be adopted as part of the standard.

6.5.4 Recommendation for the Standard. The recommendation for the standard is that time stamping be achieved using the method recommended in Position Paper [8] and described above with the addition of allowing the LSB to indicate whether the timestamp is absolute or relative. The timestamp is described in more detail in Section 5.3.19 of the standard.

6.6 PDU Length Indicator in the PDU Header

Many communication protocols carry PDU length fields in their headers so to facilitate the sending and receiving processes. When the PDU is of variable length, the PDU length indicator provides the PDU length information to the receiver without the need to go through the entire PDU.

6.6.1 Recommendation of the 7th workshop. After some discussion on this issue, the ITMC subgroup recommended the use of the fourth octet in the header, which was a padding field, to indicate the length of the entire PDU (including the header itself) in 4-byte words.

6.7 Articulation Parameter Representation

A simulation entity may carry a number of articulated parts (such as a turret of a tank) or attached parts (such as a aircraft missile). The parts are indicated by the Articulation Parameter Record in the PDUs. Depending on the type of the articulated or attached part, more than one articulation parameter may be necessary to represent it.

6.7.1 Recommendation of the 7th Workshop. After some discussion, the ITMC subgroup decided to change the representation of parameters Extension and Position. The Extension was changed from a 32-bit integer representing a percentage of its allowed extension to a 32-bit floating point number representing the extension in meters. The Position parameter was changed from 32-bit integer ranging from 0-100 to a 32-bit floating point number ranging from 0.0 to 1.0, representing fully retracted and fully extended respectively.

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7. OTHER AREAS FOR FURTHER RESEARCH

7.1 Communications Architecture

7.1.1 OSI Reference Model. Since the emerging standard and the preceding conferences were concerned primarily with interoperability, the concept of Open Systems has become an important issue. This subject has been dealt with thoroughly by the International Organization for Standardization (ISO), whose primary concern is the communication between heterogeneous computer systems developed by different vendors. ISO's efforts have led to the development of the Open Systems Interconnection (OSI) Reference Model (see Appendix A1). This reference model will be used throughout this section for discussion of communication architecture.

7.1.2 Interoperability Requirements for DIS. The interoperability requirements for communication have been well defined in the OSI reference model. DIS requires certain services not currently offered in available OSI protocols. Some of the services that have been identified are discussed in the following paragraphs.

7.1.2.1 Guaranteed Service for Real-Time Simulation. The requirements for DIS are based mainly on the needs of real-time simulation. Real-time simulation requires information on a "timely" basis, so that the representation of tracking of objects in the simulation can be accomplished as they are occurring. This requirement calls for a communication architecture that can deliver a message in a timely manner.

7.1.2.2 Multicasting Capabilities. It is sometimes necessary to send messages to a subset of nodes on the network. If a message is to be sent to all entities, it is sent using broadcast. If the message is to be sent to a specific group (as would be the case if more than one exercise is taking place on the same network), the communications method used is termed multicasting.

7.1.2.3 Appropriate Security Levels. Security is an important requirement for DIS, but there are many problems which remain unresolved. Some of these problems are related to how classified information may be securely transmitted. Another problem is how to keep the entire network secure. There has to be a mechanism by which these issues can be addressed.

7.1.2.4 Connectionless Service. A connectionless service transmits data by simply sending the data out onto the network and addressing it to the entity or entities that require it. There is no need to establish a connection between simulation entities before transmitting data. This is a requirement for multicast service.

7.1.3 Position Papers. In several position papers, some issues were raised concerning the architecture associated with Distributed Interactive Simulation (DIS). Since SIMNET was the first to accomplish DIS on a large scale, many of the issues in the position papers deal with the SIMNET architecture and its ability to interoperate with existing simulators built by different companies. Because this standard does not seek to establish a standard network architecture, the issues presented in the position papers are summarized for informational purposes only.

One architecture issue was whether or not the SIMNET architecture was OSI compliant. Four position papers deal specifically with this issue (see Position Papers [16], [24], [39], and [40]).

7.1.3.1 Position Papers [16] & [24]. Position Paper [16] proposes the evolution of the SIMNET architecture from its present form to a more OSI like profile, and eventually to an Integrated Services Digital Network (ISDN). Position Paper [24] (written by the same author) discusses the disadvantages of adopting the architecture of SIMNET as a standard for the interoperability of defense simulations. A new architecture called Distributed Simulators Architecture (DSA) is presented along with a different approach to developing a standard for interoperability.

7.1.3.3 The Author's Recommendations. The author of Position Papers [16] and [24] recommends that Distributed Simulators Architecture be adopted as the standard simulation networking architecture. Interactive Simulation Protocol (ISP) (the application layer protocol for DSA) and other layer services should be developed according to working groups formed to deal with specific layers of the OSI model. Abstract Syntax Notation One (ASN.1) should be adopted as the Presentation Layer standard for representation of Protocol Data Units (PDU) in the Application Layer.

7.1.3.4 Position Paper [39]. This paper was written as a response to Position Papers [24] and [27] on Distributed Simulation Protocol and Interactive Simulation Protocol. The paper addresses several claims made by Position Paper [24] concerning SIMNET protocol and architecture. A memo was attached to this paper making comments concerning the intended purpose of the OSI Reference Model.

7.1.3.5 The Author's Recommendations. The author of Position Paper [39] concludes that SIMNET protocols are appropriate for use in an application layer standard. The author recommends that standards work proceed to define an application layer protocol at this time, with other layers handled in an ad-hoc fashion until a solution is found that would best support distributed simulation.

7.1.3.6 Position Paper [40]. This paper presents a discussion of architectural and communication models that support a wide spectrum of future networking applications. The following topics are addressed:

a. An introduction of a new architecture called Simulation Internet Architecture (SIA) (details are provided in Position Paper [42]).

b. A discussion of the communication model needed for distributed simulation is presented and SIMNET's shortcomings are pointed out.

c. A discussion of security is presented and several types of PDUs are recommended.

7.1.3.7 Author's Recommendations. This position paper recommends that the standard define a simulator and its interface to the network, but the network should not be treated as an entity. The paper also recommends that the architecture be open and maintain the connectionless nature of SIMNET. Query PDUs should be included as part of the application layer protocol and all non-simulation protocols (such as SIMNET's Association and Data Collection PDUs) should not be included in the standard. In addition, the standard should not include intelligent network operations and SIMNET's Simulation Control Console. Finally, this paper recommends that the standard should not define simulator-specific operations such as initialization.

7.1.3.8 CASS Standards and Communication Architecture Issues. The CASS group addresses issues related to Communication Architecture. As of the Fifth Workshop in September 1991, the CASS group has begun to publish several working draft documents for DIS communications. Future communication architecture issues and progress will be reported in the context of the CASS documents since they are not within the scope of this draft standard.

7.2 Unmanned Forces

One type of entity that is represented in a simulated battle is the unmanned force. These unmanned forces are also referred to as Intelligent Forces or Semi-Automated Forces (SAFOR). These entities are computer-simulated and are not representations of crude simulators (although in a simulation exercise, SAFOR should be indistinguishable from manned simulators). As simulated entities in the exercise, unmanned forces have many of the same requirements as manned forces. The data messages (PDUs) communicated on the network are the same as those generated by manned simulators. Unmanned forces, however, have some unique informational and database requirements that other entities do not have. Because this topic is not part of the scope of this standard, a summary of the position papers that address unmanned forces is provided for informational purposes.

7.2.1 <u>Position Paper [18]</u>. Position Paper [18] gives an excellent summary of the operational and informational requirements for unmanned forces. These requirements are listed in the following paragraphs.

7.2.1.1 <u>Operational Requirements for Unmanned Forces</u>. Operational requirements for unmanned forces are listed as follows:

a. Behavior that does not differentiate an unmanned vehicle from a manned vehicle.

b. Ability to receive orders as would a manned vehicle.

c. Behavior that is appropriate for a similar manned vehicle so that the commander can anticipate it.

d. "Seamless" integration of manned and unmanned forces. The concept of "seamlessness" includes the ability of the unmanned force to:

   1. Mimic the cognitive capabilities of their human counterparts.

   2. Perceive the environment, update and maintain a model of the developing tactical situation, plan actions, monitor their execution, and communicate.

   3. Perceive the environment, react to commands, and plan simple actions.

   4. Plan routes satisfying practical requirements for timeliness and stealthy operation based on information about terrain, weather, logistics, and enemy forces.

   5. Only have information available to them that is consistent with the information possessed by the human crews.

   6. Carry out their plans and recognize factors that influence their outcome.

   7. Replan to take advantage of new information or opportunities.

   8. Detect enemy and friendly vehicles and recognize the difference.

   9. Differentiate among various vehicle and threat types.

   10. Select aim points and appropriate weapons and to lay the weapons on the targets.

   11. Work interactively to solve tactical problems.

7.2.1.2 Informational Requirements for Unmanned Forces. The following information is required for unmanned forces:

a. Terrain and environmental information.

b. Background information for operations including friendly and enemy doctrine, tables of organization and equipment (TO&E), equipment capabilities, and "signatures".

c. Information about the local battlefield.

d. "Scene" data which would ordinarily be perceived by a human crew member.

e. Intercommunication between manned and unmanned forces.

7.2.1.3 The Author's Recommendations. The author notes that there remains much to be understood about the true requirements for unmanned forces and therefore, it is impossible to define standards today. The author recommends that the process can begin by outlining requirements and standards for terrain data and for information comprising the scene presented to the unmanned forces. These should include: data formats, database contents, and transformation processes necessary for reformulating simulation data for presentation to the unmanned force elements.

7.2.2 Position Paper [9]. Position Paper [9] points out the relation of data availability to Semi-Automated Forces (SAFOR) functionality. The author recommends that SAFOR functionality be defined before data representation is decided. The paper also suggests that data availability should be ascertained before SAFOR functionality can be decided.

7.2.3 Position Paper [19]. Position Paper [19] discusses the database requirements for Semi-Automated Forces (SAFOR) in SIMNET. The paper states that database requirements will depend on the realism required of SAFOR behavior. Two classes of SAFOR operation are defined to differentiate their individual database requirements: group operation and individual operation.

7.2.3.1 Group Operation. In group operation, groups of vehicles are simulated for the purpose of determining formations, planning routes, and coordinating between groups. database requirements would consist of standard features of a DMA database, including elevation, ground cover, and drainage. In group operation, it is assumed that a SAFOR vehicle is not in contact with another vehicle. Contact implies that the vehicle in group operation is not sufficiently close to a manned unit that detailed individual simulation is warranted.

7.2.3.2 Individual Operation. Individual operation occurs when the SAFOR vehicle is in contact with another vehicle or is a member of a platoon of which any member is in contact. Simulation requirements for individual operation include:

- Perception of the environment
- Reasoning and decision-making of the crew
- Dynamics of the vehicle
- Control of the vehicle
- Network communication

7.2.3.3 Basic Perception Requirements. The greatest database requirements will arise when simulating perceptual inputs for individual SAFOR units. The SAFOR must receive all perceptual inputs that are considered relevant to the manned vehicles, so that the SAFOR may truly behave as a manned vehicle. Basic perception requirements include:

a. Object-based representations of the following:

   - Other vehicles within direct line of sight
   - Man-made objects within direct line of sight
   - Obstacles within direct line of sight
   - Visible signs of explosions and fire

b. Sounds from nearby explosions and other vehicles.

c. Terrain features within direct line of sight for hiding and other tactical maneuvers.

d. Vehicle pitch and roll data.

e. Parts of objects, such as direction and motion of a turret on another vehicle.

f. Clouds, smoke, chaff, and other features which obscure visibility.

In general, the database must be designed so intervisibility of objects can be easily computed. SAFOR units may, therefore, require an object-based description of the visual scene.

7.2.4 Position Paper [22]. Position Paper [22] discusses the modeling of Semi-Automated Forces (SAF) for mission rehearsal, specifically aircrew team training. The perceived needs of SIMNET in this area include:

a. Increased fidelity of the "1-versus-N" projection model.

b. Increased fidelity of the SAF module.

c. Increased local area network (LAN) bandwidth.

7.2.4.1 The Author's Recommendations. Recommendations to handle the requirements of SAF developed in this position paper include:

a. Establish aircrew team training Military Characteristics (MCs).

b. Relate MCs to on-going UTSS and SIMNET-D activities.

c. Develop integrated design specifications.

d. Conduct workstation-level prototyping.

e. Conduct module fidelity and update rate requirements study.

f. Revise the SAF prototype fidelity management module.

g. Develop a SIMNET testbed at AFHRL for network experiments.

h. Refine the SAF testbed design.

i. Develop formal SAF protocol specifications.

j. Establish host hardware characteristics.

7.2.5 Position Paper [23]. Position Paper [23] discusses the development of an Operator Response Model (ORM) to ensure that (SAF) players behave in a realistic manner during a SIMNET exercise. The ORM should be able to simulate functions of the combat crew for each SAF vehicle. Basic functions of the ORM include collecting and processing tactical information, executing SAF controller commands, and engaging or providing support to manned SIMNET simulators. A potential problem pointed out in Position Paper [23] concerns timing. Accurate and realistic timing of the SAF player responses can only be achieved by simulating the actions of the crew itself. For example, it should not be possible for the SAFORM to have access to information from heads-down sensor displays and out of the cockpit view simultaneously.

7.2.5.1 The Author's Recommendation. The author of Position Paper [23] recommends that a large database of tactical responses be used to drive SAF-player behavior. This database should be implemented using a rule-based expert system. The ORM rule base should incorporate multiple responses that are appropriate for a given tactical situation, and the actual response should be selected randomly from a set of choices to make the behavior of the SAF player less predictable.

Several new databases are recommended to support ORM crew simulation:

a. Crew component task performance. This database is to house time and pilot resource requirements.

b. Crew task procedure. This database is to link component tasks together.

c. Interface to the general ORM tactics rule base. This database is to make use of crew task procedures, tactics planning, and response execution activities. This database must also contain the baseline priority for executing all task procedures.

Actions recommended to the standards group include:

a. Initiate a study to identify a preferred approach for integrating detailed operator performance models into the SAF system. This might begin with a review of existing crew workload performance simulations to determine if an existing model can be used in this application.

b. Assess the existence of core task performance data bases to support ORM crew performance simulations.

7.3 Issues Concerning Fidelity Measures.

Fidelity Measures address the allowable delay between operator action and simulated response as well as the required fidelity for representing the visual appearance or sensor imagery of an entity or the environment.

7.3.1 Delay. The allowable delay between operator action and simulation response will depend on the criticality of the task being executed by the operator. One of the most time-critical tasks in distributed interactive simulation is tracking a target just prior to firing a weapon. Consequently, the smallest acceptable delay in a DIS will be the delay between the issuance of an Appearance PDU by a target entity and the display of that entity's location on the engaging entity's display. Determination of acceptable delay will require empirical studies of operator performance under varying delay conditions.

7.3.2 Entity Appearance At Long Ranges. One shortcoming of current distributed interactive simulation is that the displays have insufficient resolution to accurately depict entities at long range, thereby preventing the engagement of these entities at a range specified in doctrine. This problem may be solved by using higher resolution displays or by color coding images too small to identify. Determination of acceptable means of increasing target identification ranges will require empirical studies of operator performance with alternative modifications to the current approach.

7.3.3 Depiction of Environmental Appearance. The appearances of environmental entities such as smoke, fog, clouds, rain, and snow need to be depicted in a manner realistic enough to achieve the training or equipment evaluation objectives. Each of these environmental entities effects visibility to a varying degree based on the density of the entity.

Five levels of density should be sufficient to meet the training and equipment evaluation objectives. Definition of how the visual system will depict the density of these environmental entities should be based on target detection range for each level of density. For example, "Fog with density level three shall produce a 50% target detection probability for the T-72 tank at ____ meters."

Control of the location, density, and size of a smoke cloud should be the responsibility of the entity that produced it. Control of the location, density, and size of other environmental entities should be the responsibility of a central evaluator.

7.3.4 Fidelity, Exercise Control, and Feedback Requirements (FECFR) Working Group and Issues of Fidelity. The FECFR (formerly the Performance Measures) working group has been addressing issues related to fidelity. As of the Fifth Workshop, the FECFR group has begun to publish draft standards for FECFR in a DIS exercise. Future fidelity issues will be reported in the context of the FECFR document since they are not part of the scope of this draft standard.

7.4 Remaining Technical Issues From Other Position Papers

A number of interoperability issues that have been discussed in various position papers are discussed in the sections that follow.

7.4.1 Dead reckoning. It has already been determined that dead reckoning is required for use with the standard. Particular dead reckoning algorithms and associated parameters need to be established. Some have been proposed and require further subgroup discussion. The Interface & Time/Mission Critical subgroup has been addressing this issue. A position paper was presented at the Fourth Workshop on the use of low order dead reckoning algorithms with highly maneuverable aircraft. It was determined that the low order method was adequate. In addition, a presentation on video was also made at the Fourth Workshop showing the effect of the use of various dead reckoning methods on displaying entity position. This video illustrated the improvement of the display when higher order dead reckoning methods (DRM) were used. Packet rates were also significantly reduced. Another position paper proposed a set of dead reckoning methods for use with DIS. A dead reckoning subgroup was formed to address the issues. DRM were recommended for use in the draft standard. The result was the addition of Appendix I as of September 1991.

7.4.2 Electronic Warfare. A number of position papers already discussed point out that there are many issues associated with electronic warfare representation that have yet to be resolved. A set of PDUs must be developed that will allow the use of electronic warfare equipment in a distributed simulation. As stated earlier, a part of the Interface & Time/Mission Critical subgroup, called the Emissions Group, has been meeting to address the issues of electromagnetic and acoustic representations.

7.4.3 <u>Tri-service Requirements for Protocol Development</u>. The standards process has just scratched the surface in determining the requirements for each of the services for a distributed interactive simulation. SIMNET was designed for the Army and lacks many features required for Air Force and Navy use. Continued progress is needed in order to define a standard that will encourage interoperability between the simulations from all of the services.

7.4.4 <u>Digital Voice</u>. Communication of voice information has been discussed in Position Paper [72], but requires discussion within the subgroups. Issues such as whether a separate network should be used for voice and what types of PDUs are required must be resolved. The Fifth Workshop marked the formation of a Radio subgroup (part of the Interface & Time/Mission Critical) to determine how DIS should communicate digital voice information.

7.4.5 <u>Testing and Evaluation of the Protocols</u>. A significant concern is the standardization of protocols that have not been tested. Prototypes must be developed to show if certain recommendations would yield the benefits that are expected. Conformance and interoperability testing will be required later to insure interoperability. Subgroup discussion is required on how this topic should be approached.

7.5 Proposed Simulation Management Protocol

IST proposes a Simulation Management Protocol (SIMAN) that could provide many of the services required by DIS. This protocol is described in Position Paper [89]. The issue of Simulation Management is now being addressed by a subgroup that has been formed within the Interface & Time/Mission Critical subgroup. This Simulation Management subgroup is addressing initialization as well as simulation management functions recommended by the FECFR working group.

Appendix A1 - The Open Systems Interconnection Reference Model

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Appendix A1 - The Open Systems Interconnection Reference Model

The design of a computer network consists of different layers or levels. Each layer is built upon its predecessor and is responsible to provide services to the higher layers in a manner transparent to the higher layers. Different network architectures may have a different number of layers or different functions within the layers. In 1984, the Open Systems Interconnection Reference Model (OSI) was developed by the International Organization for Standardization (ISO) as a model of a computer communications architecture (see Fig. A-1) The model is 'Open' because it refers to systems that are open for communication with other systems.

It is important to understand that OSI is not an architecture in and of itself. The intent of the OSI model is that protocols be developed to perform the functions of each layer. The functions provided by each layer are summarized in Table I as presented in Tannenbaum[1].

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[1]Tannenbaum, Computer Networks. Prentice Hall:1988.

Open Systems Interconnection Reference Model

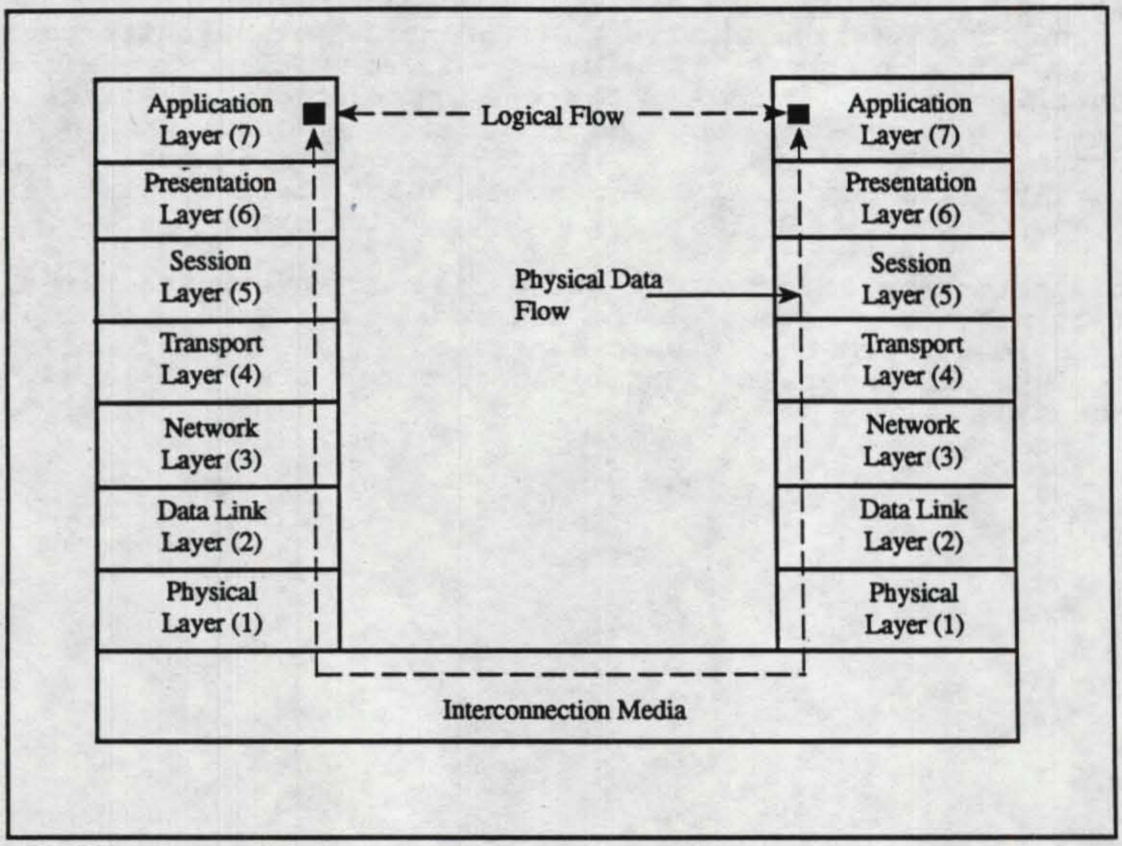

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Table I - Functions of OSI Layers

1.	Physical	Concerns the transmission of unstructured bit stream over physical medium; deals with the mechanical, electrical, functional, and procedural characteristics to access the physical medium
2.	Data link	Provides for the reliable transfer of information across the physical link; sends blocks of data (frames) with the necessary synchronization, error control, and flow control
3.	Network	Provides upper layers with independence from the data transmission and switching technologies used to connect systems; responsible for establishing, maintaining, and terminating connections
4.	Transport	Provides reliable, transparent transfer of data endpoints; provides end-to-end error recovery and flow control
5.	Session	Provides the control structure for communication between applications; establishes, manages, and terminates connections (sessions) between cooperating applications
6.	Presentation	Provides independence to the application processes from differences in data representation (syntax)
7.	Application	Provides access to the OSI environment for users and also provides distributed information services

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Appendix A2: SIMNET and its Architecture

Simulator Network (SIMNET)

Functions of Distributed Interactive Simulation have been demonstrated as a proof-of-concept in SIMNET. A brief description of SIMNET is included below.

Description. SIMNET is an advanced research project sponsored by the Defense Advanced Research Projects Agency (DARPA) in partnership with the United States Army, and was developed by Bolt, Beranek & Newman Systems and Technologies Corporation (BBN) and Perceptronics Inc. The goal of the SIMNET project has been to develop the technology to build a large-scale network of interactive combat simulators. Presently there are over 100 SIMNET simulators in place worldwide, including M1 Abrams Main Battle Tank simulators, M2/M3 Bradley Fighting Vehicles, as well as helicopter and fixed-wing aircraft simulators. The communications architecture in SIMNET uses a layered approach as does the OSI model.

Three communication protocols are used in SIMNET: Simulation, Data Collection, and Association Protocols. A brief explanation of each follows. (For more detailed information on the SIMNET architecture, see Appendix A2. For more information on SIMNET protocols, see BBN Report No. 7102.)

Simulation Protocol. The Simulation Protocol is used to introduce simulated elements into an exercise, remove them from an exercise, and convey information about the simulated world for use by the simulators.

Data Collection Protocol. The Data Collection Protocol is used to report information arising from a simulation, to assist in studying the course of an exercise, or to restart the exercise following an interruption.

Association Protocol. The Association Protocol provides some of the communication services that are particular to the needs of DIS. The Association Protocol supports the Simulation and Data Collection Protocols by conveying the messages of each simulator to the underlying communications services.

The Architecture of SIMNET

The architecture of SIMNET was designed to handle the unique needs of Distributed Simulation (DS). Three protocols handle the relay of messages in a SIMNET DS: Association Protocol Data Units (APDU), Simulation Protocol Data Units (SPDU), and Data Collection Protocol Data Units (DCPDU). In the SIMNET architecture, the SPDUs and the DCPDUs are application layer protocols that convey messages to perform specific functions of

SIMNET. The APDUs carry the SPDU and DCPDU messages to the underlying communication service, and thus serve functions corresponding to the session and transport layers of the OSI model (See Appendix A1). The relationship described above is diagrammed in Figure 1.

Simulation & Data Collection Protocol
Association Protocol
Communication Service

Figure 1 SIMNET Architecture.

The protocol is defined using a notation called Data Representation Notation (DRN). This method of presentation is unique to SIMNET. A full description of DRN is given in BBN Report #7102, Appendix A.

Appendix B - Position Papers Submitted to the Institute for Simulation and Training

December 1989 - March 1990

Appendix B - Position Papers Submitted to the Institute for Simulation and Training

[1] "Position Paper: On Adopting the SIMNET LAN Protocol as the LAN Standard", Moon, R. & Fitzgerald, R. (Evans & Sutherland) 90-1

[2] "Time/Mission Critical Issues For Networks of Simulators", George, G. (CAE-Link) 90-2

[3] "Environmental Correlation in Networks of Simulators", George, G. (CAE-Link) 90-3

[4] "Issues Affecting the Networking of Existing & Multifidelity Simulators", Knight, S. (CAE-Link) 90-4

[5] "Correlation of Environmental Databases for Networked Simulators", Schwalm, S. (CAE-Link) 90-5

[6] "Dynamic Environment Concerns for Networked Simulators", Schwalm, S. (CAE-Link) 90-6

[7] "Position Paper: On the Definition of Object Types in SIMNET Protocol", Pinon, C. (IST) 90-7

[8] "Absolute Time Stamp in Networking of Simulators", Katz, A. (McDonnell Douglas Helicopter Company) 90-8

[9] "SIMNET Database Issues", Galloway, G. (USMA) 90-9

[10] "Position Paper: Proposed Changes to the Vehicle Appearance PDU", Cadiz, J. (IST) 90-10

[11] "Issues Related to Standardized Tri-Service Simulator Networking Protocol", Glasgow, R. (IST) 90-11

[12] "Position Paper: On Adopting the SIMNET Local Area Network Deactivate Request and Response PDU's in the Local Area Network Standard", Danisas, K. (IST) 90-12

[13] "Position Paper: On Adopting the SIMNET Local Area Network Activate Request PDU in Local Area Network Standard",Williams, K. (IST) 90-13

[14] "Position Paper: On Adopting the SIMNET Local Area Network Status Change, Status Query and Status Response PDU's in the Local Area Network Standard", Williams, K. (IST) 90-14

[15] "Position Paper: On Adopting the SIMNET Local Area Network Activate Response PDU in the Local Area Network Standard", Williams, K. (IST) 90-15

[16] "Protocol Profiles for SIMNET Evolution", Kerecman, A. (USACECOM) 90-16

[17] "Use of Global Coordinates in the SIMNET Protocol", Burchfiel, J. & Smyth, S. (BBN) 90-17

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Appendix C - Recommendations From Interim Meetings of Subgroups

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Appendix C - Recommendations From Interim Meetings of Subgroups

1.0 Introduction

This appendix contains recommendations made at subgroup meetings which have taken place at times outside of the DIS workshops. The summaries contained herein are in order of meeting occurrence.

2.0 Interface, Time/Mission Critical and Communications Architecture (Long Haul) Subgroup Meetings, March 29 & 30, 1990

2.1 Interface Subgroup Meeting. The following list is a summary of the recommendations made by the group by majority vote:

a. Position - Geocentric Cartesian Coordinates, 32-bit signed integer with the least significant bit(LSB) representing1/32 of a meter.

b. Orientation - Euler angles as 32-bit signed integers in Binary Angle Measurement (Fractions of a revolution) Unit.

c. Velocities - Signed integers (32-bit) with the most significant bit (MSB) at least a factor of two greater than any known physical vehicle.

d. Floating point numbers - Should not be used.

e. Big Endian bit-ordering - Should be used.

2.2 Time/Mission Critical. The following list is a summary of the Motions made by the group and the result of the vote:

a. The length, in bytes, of ASCII character messages will be specified in a 16-bit integer field at the beginning of each message.

Yes - 12 No - 0

b. Timestamps will be 32 bits in length, with the least significant bit used to identify whether the timestamp is relative or absolute. This format will allow 2^{31} to equal 60 minutes, with the timestamp representing time since the start of the current hour. The accuracy of an absolute timestamp must be within one millisecond of UTC. Simulators with relative or absolute timestamps must be interoperable. Timestamps will be used in those PDUs which today have a timestamp field, and will be used as applicable in all newly developed PDUs.

Yes - 12 No - 0

c. Accept the Fidelity Request and Fidelity Response Protocol Data Units as presented by Art Pope of BBN for the draft standard.

Yes - 10 No - 0

2.3 Long-Haul Group. Many of the topics discussed by the Long-Haul Group (now called the Communication Architecture Group) are not directly related to present standards efforts. Their recommendations are intended for current and future research. The accomplishments of the Long-Haul Group are summarized below:

a. A Communication Architecture Outline Workplan was developed to transition the present BBN SIMNET formats into an OSI supportable application layer protocol, and a commercially available, off-the-shelf protocol profile.

b. A game plan was established to introduce the application layer protocol to the several standards groups.

c. Wide Area Network characteristics for the application layer protocol were compiled.

3.0 Interface & Time/Mission Critical Subgroup Meetings July 17 & 18, 1990

The Interface and Time/Mission Critical Subgroups had a joint meeting and made the following recommendations as a result of their discussions:

a. Timestamps:

1. The standard should accommodate both absolute and relative time stamps.

2. The LSB of the timestamp is to indicate whether the timestamp is relative or absolute.

3. The timestamp should indicate the "time at which the data is valid".

4. Absolute time is to be defined as time since the beginning of the hour in UTC; 1/2^31 of an hour is the LSB of the time field of the timestamp.

5. Relative time is to be defined as a time that is local and of arbitrary origin. The units are the same as for absolute.

6. Support of a relative timestamp by a simulator that uses absolute timestamps should be required.

b. Acceleration should be expressed in terms of Platform Coordinates. Velocity shall be expressed in World Coordinates.

c. A field should be created in the Appearance field to specify what type of dead-reckoning algorithm should be used.

d. The standard needs to obtain a better definition of direct fire and indirect fire from the army.

e. Data representation needs to specify two's compliment for representing negative numbers.

f. In Section 4.2.2 of the June 1990 draft standard, discussion of Angular velocity vector, the coordinate system should be specified as "forward-right-down" and not "north-east-down". Diagrams should be included to help alleviate confusion.

g. The following is recommended for Articulated Parts:

   1. A subgroup should be formed to specifically define and solve the problems related to articulated parts.

   2. An interim solution includes:

      - Use 16-bit BAMs instead of 8-bit BAMS for azimuth/elevation. Provide a definition of a 16-bit BAM.

      - Provide clarification for the order of parts and the frame of reference.

      - Immediately provide a form that will accommodate tank entities. Develop one for other entities after the subgroup has made its recommendations.

      - Specify a maximum number of articulated parts.

h. An Event ID needs to be included in the Collision PDU.

i. All instances of unsigned integers that are used for calculations should be specified as signed.

j. Tracers need to be represented.

k. A deactivation mechanism is required for the detonation of munition entities.

l. A classification needs to be developed for amphibious vehicles.

m. Emitter PDU requires the following changes:

1. It is recommended that the Radar PDU, with the addition of a Timestamp, be used for emitter information at this time.

2. Future studies should include developing the database information required for a PDU such as the present Emitter PDU.

n. Check the definition of the word multicast and consider redefining.

o. Detonation PDU requires the following changes:

1. Include identification of the vehicle that is impacted.

2. Include the location of detonation in Vehicle Coordinates to help the entity determine damage.

3. Consider having the standard provide either two PDUs that are similar in function to SIMNET's Impact and Indirect Fire PDU's or one PDU that combines both functions.

4. Tracers are to be defined as entities so their appearance can be described.

p. Certain requirements need to be clarified:

1. State diagrams should be incorporated where applicable.

2. The production of a Handbook to accompany the draft standard should be considered.

q. Guises should be included in the draft standard. Some study should be done in order to make the function more generic.

r. The foreword should be more specific about not including data collection or instruction stations as entities on the network. The foreword should be specific about certain other protocols that may be included in the standard in the future (data collection, management, terrain change.

4.0 Communications Architecture & Security Subgroup Meeting, June 1991

The Communication Architecture & Security Subgroup (CASS) met to discuss Communication Architecture service requirements, a transition plan, and topics for the September 1991 workshop. In addition, CASS made a number of recommendations for the DIS standard. Many were editorial in nature. All detailed recommendations can be found in the minutes from this CASS meeting. Noteable recommendations are listed below:

a. Change paragraph 1.1, page 1 to read: "These standards define an application process that would utilize the International Organizations for Standardizations (ISO) Open Systems Interconnection (OSI) Reference Model (see Appendix A)." Justification - the CASS group believes that the DIS PDU standard is not a protocol within the application layer, but rather an application process that uses the protocols within the application layer.

b. Change paragraph 3.8, page 5, by adding the following sentence to the definition of Byte: "For standardization, the term "octet" is preferred." This change also includes a recommendation to change all references to "byte and bytes" with the term "octet" and "group of octets." Justification -all ISO standards documents use this convention because the definition of byte varies according to machine architectures. Octet is a more precise term.

c. Change paragraph 3.9, page 5, by using the ISO 7498 standard definition for Connectionless service. The definition should be stated as follows: "Connectionless-mode transmission is the transmission of a single unit of data from a source service-access-point to one or more destination service-access-points without establishing a connection. A connectionless-mode service allows an entity to initiate such a transmission by the performance of a single service access."

d. Change paragraph 3.12, page 5, by changing definition to "an exercise that involves the interconnection of a number of simulated and/or real devices in which the simulated entities are able to interact within a computer generated environment. The simulated or real devices may be present in one location or distributed geographically." Justification - CASS believes that "real" devices should be specified in the definition for accuracy and that it was not necessary to be specific about the WAN or LAN.

e. Change paragraph 3.27, page 7, by expanding the multicast definition to match existing definitions by adding: "where a single message is sent to multiple destinations. May include concentration where more than one host transmit arbitrary messages to a single host. Typical multicast systems are based upon the precepts of connectionless data transmissions. This implies that no error recovery or retransmission procedures are used if some stations do not receive a given message. Multicast is distinctly different from broadcast technology. In multicast, the transmission is one-to-many, with defined groups, whereas broadcast is one-to-all."

5.0 Emissions Subgroup Meeting, August 1991

The Emissions subgroup of the Interface & Time/Mission Critical Subgroup met in July 1991 in Orlando to discuss the difficult problem of communicating electromagnetic and acoustic information in a DIS exercise. Items discussed at the August meeting include: emitter categories, architecture concepts, PDU concepts, and the use of multiple PDUs to reduce processing. Issues applicable to several of the DIS subgroups were identified. A number of issues still remained open at the close of the meeting. Several briefings are planned for the September 1991 workshop subgroup meeting on ECM/ECCM, alternate Emission PDU methodology, meeting Naval surface and subsurface requirements, and audio communications.

6.0 Performance Measures Working Group Meeting, August 1991

The performance measurement subgroup held an interim meeting at IST on 20-22 August 1991. Attendees are listed in attachment A. The meeting began with a recap of the prior meeting in March 1991. Discussions/demonstrations were conducted in the following areas:

- Larry Meliza of ARI and Seng Tan of IST demonstrated the Unit Performance Assessment System (UPAS). UPAS is PC-based data collection software designed to work with SIMNET exercises. We discussed the capabilities and future enhancements planned for UPAS and how that might be used as a DIS data collection/performance measurement tool.

- The Performance Measurement Subgroup provided input and comments to a working draft standard strawman presented by Bruce McDonald. These comments will be incorporated in the standard and will be presented at the September 1991 Workshop.

- Ken Morris from Northrup Corporation showed a videotape of the effects of different dead recognizing algorithms on high performance aircraft. It was recommended that this tape be shown at the September meeting.

- Planned studies briefings were conducted on the following topics: Intersimulator transmission delays (Kevin Uliano), Target/Background Contrast (Kevin Uliano), Intervisibility (Kevin Uliano), and Dead Reckoning (Bruce McDonald).

Appendix D - SUMMARY OF WORKSHOPS ON STANDARDS FOR THE INTEROPERABILITY OF DEFENSE SIMULATIONS

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Appendix D - SUMMARY OF WORKSHOPS ON STANDARDS FOR THE INTEROPERABILITY OF DEFENSE SIMULATIONS

1.0 Introduction

The following is a brief summary of the Workshops on Standards for the Interoperability of Defense Simulations. Please see the individual Summary Reports for each workshop for details concerning the meeting that took place.

2.0 The First Conference on Standards for the Interoperability of Defense Simulations, 22-23 August 1989

The two day workshop focused on Network Communications and Terrain Databases.

2.1 Terrain Databases Working Group Summary

The main objectives of this working group were to establish an understanding of terrain database issues necessary to support development of interoperational network simulation standards and to set up a mechanism for working issues to support these efforts.

The Terrain Database Working Group identified the following action items during the course of the workshop:

- Coordinated efforts with DMA.
- Interim Terrain Data Assessment.
- Project 2851 Engineering Change Proposal.
- The need for a Geodetic frame of reference system.
- Investigation of correlation parameters and metrics.
- Investigation of dynamic terrain issues.

Three additional subgroups were formed to investigate these issues:

- Correlation
- Dynamic Terrain
- Unmanned Forces

2.2 Communication Protocol Working Group Summary

The main objective of this working group was to determine whether the existing SIMNET Network and Protocols (July 31, 1989) would be suitable as a networking standard, and if not, to recommend modifications and/or extensions to the SIMNET protocol in order to implement networked simulations. Another objective for this working group was to find persons willing to identify issues and work to achieve an interoperability standard for simulation systems using a formal standardization procedure.

The Communication Protocol Working Group identified the capabilities that must be present to support requirements for the standard. As the protocol standard evolves, it must be able to:

•Support simulators with different levels of fidelity.

•Scale up and down.

•Support time critical applications.

•Incorporate additional entities.

•Support voice and data communication.

•Incorporate environmental effects.

•Provide different levels of security.

•Address machine dependent issues (external vs. internal) representation.

•Increase the size of the game board.

•Use Ada for encoding the PDUs.

•Interface with a live exercise environment.

•Determine events that require guaranteed delivery.

•Address non-visual issues.

•Have adaptive thresholds.

•Use an absolute clock time.

•Annotate location.

•Prioritize the standard process.

•Address Communication Architecture issues.

Four additional subgroups were formed to investigate these issues:

a. Interface

b. Time/Mission Critical

c. Non-Visual/Security

d. Long Haul/Wide Area Network

3.0 The Second Conference on Standards for the Interoperability of Defense Simulations, 15-17 January 1990

3.1 <u>Terrain Databases Working Group Summary</u>

3.1.1 <u>Correlation Subgroup</u>. Important points are summarized as follows:

a. A requirement is needed to minimize visual anomalies and maximize line of sight correlation.

b. Experimentation is needed with the correlation of different simulators.

c. The correlation of images on different types of sensors is important.

d. Operational measures like target detection probability and identification probabilities are an important consideration.

e. A determination of how to measure correlation and how much correlation is considered enough needs to be made.

3.1.2 <u>Dynamic Terrain Subgroup</u>. Conclusions for this working group are summarized as follows:

a. Dynamic terrain needs to be defined and methodology needs to be determined.

b. The simulator world needs to be recreated from the beginning, defining the effects that are desired and categorizing them.

c. Development of correlation parameters in metrics is needed as a means to improve interoperability.

d. Solid modeling techniques and definition of texture representation needs to be defined.

3.1.3 <u>Unmanned Forces</u>. The following recommendations were made by this group:

a. Vector and point representation should be allowed and encouraged in the standard that is to be developed because polygons are not enough.

b. Clearer objectives need to be established.

c. Terrain database and Vehicle database need to be expanded.

d. The standard should allow for object oriented databases.

e. The SAFOR standard needs to allow for universal threat system.

f. PDUs should contain sensor data.

3.2 Communication Protocols Working Group Summary

3.2.1 Interface Subgroup. Two resolutions were made in the Interface subgroup:

a. The Geocentric Cartesian Coordinate System should be the reference frame for passing positional data.

b. The networking protocols and database standards that are being developed are not sufficient and an administrative mechanism is essential.

3.2.2 Time/Mission Critical Subgroup. The following recommendations were made by the Time/Mission Critical subgroup:

a. Keep the timestamp field in the protocol, but add another field to identify whether or not it is a relative or an absolute. Keep the least significant bit at suggested 0.838 microseconds.

b. Define a higher order vehicle class to support the higher order velocity derivatives in upgraded dead reckoning algorithm.

c. Establish explicit data representation.

d. Add a priority field to the PDU field, the value of 0 to be the lowest priority and 15 to be the highest.

e. Develop dynamic air criteria capability for aircraft simulators.

f. Provide control level PDUs (freeze, reset, reposition).

3.2.3 Non Visual/Security Subgroup. The conclusions from this subgroup are as follows:

Non Visual:

a. The current protocol has minimal sensor and electronic warfare capability.

b. PDUs need to be expanded to represent sensors of all types. The VOR should be approached in a dynamic terrain sense and be interactive.

Security:

a. To address the problem of transmitting unclassified and encrypted classified information on the same network, two recommendations were made:

1. Secure the exercise as a classified operation.

2. Use a special gateway to separate classified and unclassified information.

b. Issues associated with the approaches above need to be further discussed.

3.2.4 Long Haul/Wide Area Network Subgroup. Several points of discussion were developed by this subgroup:

a. Handling security at the gateway

b. Definition of the present protocol profile and its mapping into ISO reference model

c. Time stamping and latency issues

d. The recommended profile for the SIMNET specification and the consideration and participation with NATO

e. The additional service requirements that are driven by the joint and service doctrinal guidance

f. Bringing NIST, ITS, NTIA, and university contributions into a possible evolution

g. C&I testing and verification and validation of those simulators

h. Database configuration and configuration management

4.0 The Third Workshop on Standards for the Interoperability of Defense Simulations, 7-8 August 1990

The two day workshop focused on three major topic areas: Communication Protocols, Terrain Databases, and a new area called Performance Measures.

The following paragraphs are a summary of recommendations made by the different subgroups:

4.1 Communications Protocols Working Group

4.1.1 Interface & Time/Mission Critical Subgroups

a. Orientation should be represented using Euler angles.

b. Angles should be represented in Binary Angular Measurement (BAM), with orientation being 32-bit BAMS and articulated parts, represented in 16-bit BAMS. The definitions of what the 16 and 32-two bit BAMS are will be specified in the standard as well.

c. The Appearance PDU should have an additional field appended to it designating a dead reckoning class, or a dead reckoning type. The contents of the dead reckoning algorithm will be followed up by a subgroup which will delineate the algorithms, the equations, and the numerations that will be used in that field.

d. Simulation management functions should establish the default update thresholds and establish a minimum default update rate.

e. Articulated Parts representation should be used to represent orientation of articulated parts. A subgroup will address that.
f. The Detonation PDU should contain the following information:

1. Coordinates in terms of the target

2. Coordinates of the detonation location in terms of the world

3. Energy and directionality

4. The result of the detonation

g. Timestamps should be 32-bit unsigned integers. Each hour will be divided into 2^{31} parts and, when necessary, there will be a mechanism (the LSB) to specify the timestamp as relative to the hour or absolute.

h. The ACME Radar PDU should be used as an interim solution for emissions. A subgroup is continuing to work out the details.

i. Muzzle flashes should be represented using information in the Fire PDU. The muzzle flash bits should be removed from the Appearance field in the Entity Appearance PDU.

j. Angular rotation rates should be represented by 32-bit signed integers representing BAMs per millisecond.

k. World coordinates should be represented by three 64-bit floating point numbers. Entity coordinates should be represented by three 32-bit floating point numbers.

4.1.2 Communications Architecture Subgroup

Services identified by the Communications Architecture subgroup as necessary for DIS are:

a. Multi-cast and broadcast capability

b. Point-to-point capabilities

c. Real-time delivery (less than five hundred milliseconds buffer to buffer)

d. Packet delivery done in sequence as required

e. Minimum delay dispersion

f. Minimum packet loss rate

g. LAN to WAN capabilities

h. Classified and unclassified capabilities with authentication when used in classified exercises

i. ISO/CCITT guidance for site address assignments

j. A schema to identify specific multi-cast groups

k. A transaction protocol to support the simulation management functions

4.2 Terrain Database Working Group

A database dictionary should be established to handle label binding information (such as country codes).

4.3 Performance Measures Working Group PDUs:

a. Performance Measures Request PDU. This PDU allows an evaluator to request certain previously defined performance measures from a simulator.

b. Generic Performance Measures PDU. This PDU is issued by a simulator in response to the Performance Measures Request PDU.

c. Observed Event PDU. This PDU allows events not normally reported to be recorded to aid in evaluating a sequence of actions.

Recommendations for the Draft Standard:

I. Hierarchical Entity descriptions, as presented in position papers, should be used.

II. Five levels of obscuration should be defined in terms of atmospheric parameters such as humidity and temperature.

III. Articulated Parts:

1. The following parts do not need to be represented:

- rudders or ailerons
- rotating antenna

2. Submarine parts such as periscope, snorkel, radar, missile launcher, and ESM loop are either up or down and therefore, are not articulating parts.

3. Speed brakes need to be represented.

5.0 The Fourth Workshop on Standards for the Interoperability of Defense Simulations, 13-15 March 1991

The three day workshop focused on three major topic areas. These are: Communication Protocols, Simulated Environments, and Performance Measures. Attention was focused on making final recommendations for the draft standard.

The following paragraphs are a summary of recommendations made by the different subgroups:

5.1 <u>Communications Protocols Working Group</u>

5.1.1 <u>Interface & Time/Mission Critical Subgroups</u>

a. The following PDUs should be accepted for the draft standard: Entity State, Fire, Detonation, Service Request, Repair and Resupply PDUs, Collision, and the PDU header (with minor changes made).

b. Move the Radar PDU to Section 6 of the document until the issue can be more thoroughly dealt with.

c. Remove the Update Threshold PDUs from the document.

d. Entity state PDUs should be issued for munitions "for which in-flight data is required" rather than "for guided munitions."

e. The rate field in the Detonation field should be in munition output per minute rather than per second.

f. Like field in the various PDUs should be placed in the same positions within the PDU.

g. The shape of the world for the world coordinate system should correspond to the WGS-84 standard.

5.1.2 Communications Architecture Subgroup. The CAS subgroup worked on issues related to defining the communication architecture that will be used by the PDU standard as well as addressing issues related to security. No recommendations were made concerning the current PDU draft standard.

5.2 Simulated Environment Working Group. This working group replaced the former Terrain Databases working group. Issues related to terrain are now to be dealt with in the Land subgroup of the Simulated Environment working group. Other subgroups include: Air, Sea, and Cross Environments. Recommendations for these groups are included below.

5.2.1 Land.

a. Specify the world coordinate system as World Geodetic System 1984 (WGS-84).

b. Use the DIA manual for establishing country names and abbreviations.

c. Use the DoD standard for feature attributes coding as much as possible.

d. Characterize the concept of a fair fight.

e. Narrow the definition of what high, medium, and low level of detail is.

f. Use available DMA standard products where appropriate.

g. Accelerate research on dynamic terrain and support the development of Project 2851.

5.2.2 Sea. No recommendations were made for the current draft PDU standard.

5.2.3 Air. No recommendations were made for the current draft PDU standard.

5.2.4 Cross-Environments. No recommendations were made for the current draft PDU standard.

5.3 Performance Measures Working Group.

a. Tracers should be modeled.

b. Weapons handover PDU should be used to allow entities to take control over a munition entity.

c. Update Threshold Control should be used to help reduce the number of necessary messages on the network.

6.0 The Fifth Workshop on Standards for the Interoperability of Defense Simulations, 24-26 September 1991.

The three day workshop focused on three major topic areas. These are: Communication Protocols, Simulated Environments, and Performance Measures. With the first draft standard finished, the groups began work on revision 1 of the PDU standard, and new drafts issued by the Performance Measures group and the CASS group. Recommendations from this workshop did not affect the October draft standard. They are stated here for reference.

6.1 Communication Protocols Working Group.

6.1.1 Interface & Time/Mission Critical Subgroup. This group began work in the area of new PDUs for Revision 1 of the draft standard. A number of position papers were presented in the areas of Simulation Management, Digital Voice, Radio, Handover PDU, Dead Reckoning, and Emissions.

6.1.2 Communication Architecture and Security Subgroup. This group presented its draft document with communication requirements and definitions section completed. Work continued on various sections of the CASS document.

6.2 Simulated Environments Working Group.

6.2.1 Land Subgroup. Issues discussed in this group include:

a. Correlation between dissimilar simulators and between visual and sensor simulators. Acceptable degree of correlation was also discussed.

b. Classifying simulators according to functionality and performance characteristics

c. The concept of an Environment server on the network

6.2.2 Sea Subgroup. Issues discussed in this group include:

a. Definition of Environment parameters

b. Identification of models, databases and additional requirements

c. Definition of Environmental entity PDUs

6.2.3 Air Subgroup. The subgroup changed its name to "Atmosphere" subgroup. The group discussed atmospheric representations or variables and whether or not they changed with time (static or dynamic). Natural and man-made phenomena were discussed. The group's focus will be on identifying various models for atmospheric representation.

6.2.4 Cross-Environment Subgroup. This group discussed how new players might become involved with DIS.

6.3 Fidelity, Exercise Control, and Feedback Requirements Working Group. This group began work on its draft standard. Discussions included exercise management functions, target/background contrast, required correlation for terrain/feature databases, and three new PDUs. These are: Observed Event PDU, Generic Performance Measure PDU, and the Query PDU.

In order to keep this document focused, no more workshop summaries will be provided in this document. Please refer to Workshop Summary document for workshop related information.

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Appendix E - Basic Concepts of Distributed Interactive Simulation

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Appendix E - Basic Concepts of Distributed Interactive Simulation

The basic concepts of Distributed Interactive Simulation (DIS) are an extension of the Simulation Networking (SIMNET) program developed by the Defense Advanced Research Projects Agency (DARPA). The purpose of DIS is to allow dissimilar simulators distributed over a large geographical area to interact in a team environment for the purposes of training, equipment development, or equipment evaluation. These simulators communicate over local area networks and wide area networks. The basic DIS concepts are:

(1) No central computer controls the entire simulation exercise.
(2) Autonomous simulation applications are responsible for maintaining the state of one or more simulation entities
(3) A standard protocol is used for communicating "ground truth" data
(4) Changes in the state of an entity are communicated by simulation applications
(5) Perception of events or other entities is determined by the receiving application
(6) Dead reckoning algorithms are used to reduce communications processing

The implications of each of these concepts as they apply to DIS are discussed in the following paragraphs.

No Central Computer

Some war games have a central computer that maintains the world state and calculates the effects of each entity's actions on other entities and the environment. These computer systems must be sized with resources to handle the worst case load for a maximum number of simulated entities. DIS uses a distributed simulation approach in which the responsibility for simulating the state of each entity rests with separate simulation applications residing in host computers connected via a network. As new host computers are added to the network, each new host computer brings its own resources.

Autonomous Simulation Applications

Simulation applications (or simulations) are autonomous and generally responsible for maintaining the state of one entity. In some cases, a simulation will be responsible for maintaining the state of several entities. As the user operates controls in the simulated or actual equipment, the simulation is responsible for modeling the resulting actions of the entity using a high fidelity simulation model. That simulation is responsible for sending messages to others, as necessary, to inform them of any observable actions. All simulations are responsible for interpreting and responding to messages of interest from other simulations and maintaining a model of the state of entities represented in the simulation exercise. Simulations may also maintain a model of the state of the environment and nondynamic entities, such as bridges and buildings, that may be intact or destroyed.

Ground Truth Versus Perception

Each simulation application communicates the state of the entity it controls (location, orientation, velocity, articulated parts position, etc.) to other simulations on the network. The receiving simulation is responsible for taking this ground truth data and calculating whether the entity represented by the sending simulation is detectable by visual or electronic means. This perceived state of the entity is then displayed to the user as required by the individual simulation.

Dead Reckoning

A method of position orientation estimation, called dead reckoning, is used to limit the rate at which simulations must issue state updates for an entity. Each simulation maintains a high fidelity model of the entity it represents. In addition, the simulation maintains a simpler model of its entity. The simpler model represents the view of that entity by other simulation applications on the network and is an extrapolation of position and orientation state using a specified dead reckoning algorithm. On a regular basis, the simulation compares the high fidelity model of its entity to the simpler model of the entity. If the difference between the two exceeds a predetermined threshold, the simulation will update the simpler model using the information from the high fidelity model. At the same time, the simulation will send updated information to other simulations on the network so that they can update their model of the entity. By using dead reckoning, simulations are not required to report the status of their entities every frame.