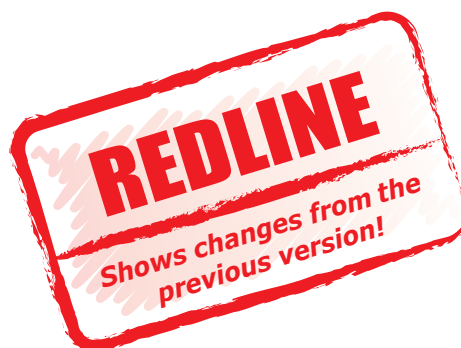


IEEE Standard for Distributed Interactive Simulation— Application Protocols

IEEE Computer Society

Sponsored by the
SISO Standards Activity Committee



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IEEE Std 1278.1™-2012
(Revision of
IEEE Std 1278.1-1995)

19 December 2012

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IEEE Std 1278.1-1995)

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Sponsor
SISO Standards Activity Committee
of the
IEEE Computer Society

Abstract: Data messages, known as Protocol Data Units (PDUs), that are exchanged on a network among simulation applications are defined. These PDUs are for interactions that take place within specified domains called protocol families, which include Entity Information/Interaction, Warfare, Logistics, Simulation Management, Distributed Emission Regeneration, Radio Communications, Entity Management, Minefield, Synthetic Environment, Simulation Management with Reliability, Information Operations, Live Entity Information/Interaction, and Non-Real-Time protocol.

Keywords: data messages, Distributed Interactive Simulation, IEEE 1278.1™, protocol data units (PDUs), simulation network

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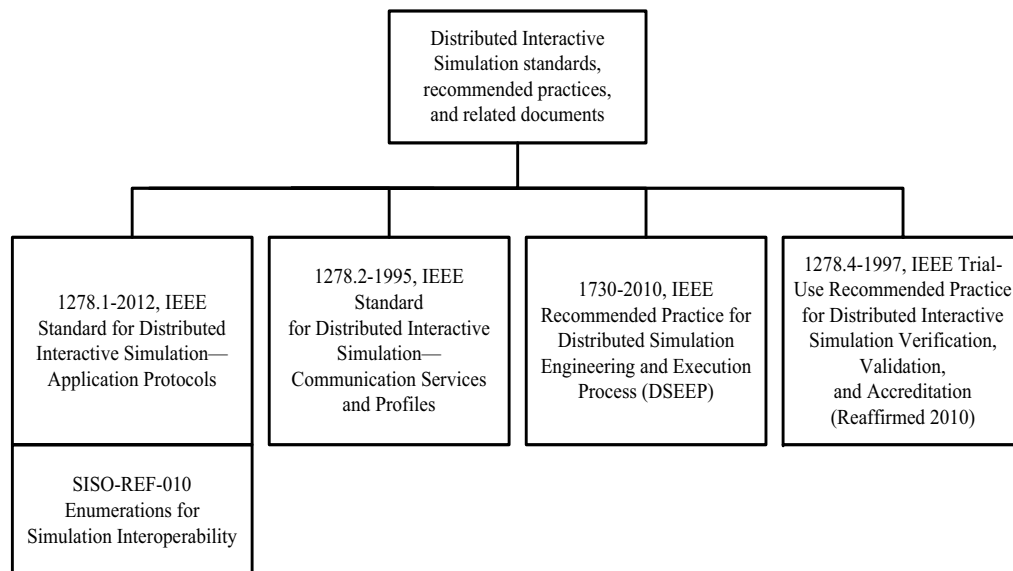
Introduction

This introduction is not part of IEEE Std 1278.1-2012, IEEE Standard for Distributed Interactive Simulation—Application Protocols.

This edition of IEEE Std 1278.1 supersedes both IEEE Std 1278.1-1995 and the material included in the IEEE Std 1278.1a-1998 amendment. Distributed Interactive Simulation (DIS) is a government/industry initiative to define an infrastructure for linking simulations of various types at multiple locations to create realistic, complex, virtual worlds for the simulation of highly interactive activities. This infrastructure brings together systems built for separate purposes, technologies from different eras, products from various vendors, and platforms from various services and permits them to interoperate. DIS exercises are intended to support a mixture of virtual entities with computer-controlled behavior (computer-generated forces), virtual entities with live operators (human-in-the-loop simulators), live entities (operational platforms and test and evaluation systems), and constructive entities (wargames and other automated simulations). DIS draws heavily on experience derived from the Simulation Networking (SIMNET) program developed by the Advanced Research Projects Agency (ARPA), adopting many of SIMNET's basic concepts and heeding lessons learned.

For DIS to take advantage of currently installed and future simulations developed by different organizations, a means had to be found for assuring interoperability between dissimilar simulations. These means were developed in the form of industry consensus standards. The open forum (including government, industry, and academia) chosen for developing these standards was a series of semiannual Workshops on Standards for the Interoperability of Distributed Simulations that began in 1989. The workshops resulted in several IEEE standards and recommended practices.

The relationship between the component documents constituting the set of IEEE DIS documents is shown in the following figure. Used together, these standards and recommended practices will help produce an interoperable simulated environment.



Documentation relationships

The interoperability components addressed by these standards and recommended practices are as follows:

- Application protocols
- Communication services and profiles
- Distributed simulation engineering and execution
- Verification, validation, and accreditation

IEEE Std 1278.1-2012 defines the format and semantics of data messages, also known as Protocol Data Units (PDUs), that are exchanged among simulation applications and simulation management. The PDUs provide information concerning simulated entity states, types of entity interactions that take place in a DIS exercise, data for management and control of a DIS exercise, simulated environment states, aggregation of entities, and the transfer of ownership of entities. This standard also specifies the communication services to be used with each of the PDUs.

An additional, non-IEEE document is required for use with IEEE Std 1278.1-2012. This document is titled Enumerations for Simulation Interoperability and is available from the Simulation Interoperability Standards Organization, Orlando, Florida.

IEEE Std 1278.2TM-1995^a defines the communication services required to support the message exchange described in IEEE Std 1278.1-2012. In addition, IEEE Std 1278.2-1995 provides several communication profiles that meet the specified communications requirements.

Together IEEE Std 1278.1-2012 and IEEE Std 1278.2-1995 provide the necessary information exchange for the communications element of DIS.

IEEE Std 1730TM-2010 [B5]^b is a recommended practice defining the processes and procedures that should be followed by users of distributed simulations to develop and execute their simulations; it is intended as a higher level framework into which low-level management and systems engineering practices native to user organizations can be integrated and tailored for specific uses. This recommended practice is intended to replace IEEE Std 1278.3TM-1996 [B4]. This recommended practice is used in conjunction with IEEE Std 1278.1-2012 and IEEE Std 1278.2-1995.

IEEE Std 1278.4TM-1997 provides guidelines for verifying, validating, and accrediting a DIS exercise. This recommended practice, used in conjunction with IEEE Std 1730-2010 [B5], presents data flow and connectivity for all proposed verification and validation activities and provides rationale and justification for each step.

The principal changes between IEEE Std 1278.1TM-1995 and IEEE Std 1278.1aTM-1998 and the present standard are as follows:

- a) Extensive clarification of requirements throughout the standard.
- b) The general requirements have been expanded to cover detailed requirements related to simulations, enumerations, objects, heartbeats, timeouts, thresholds, gateways, and communication services.
- c) All identifiers used in the standard have been clarified, and consistent, simplified terminology has been adopted.
- d) To provide flexibility and reduce the number of heartbeats, entity heartbeats are now defined by entity kind, domain, and whether the entity is moving or stationary.
- e) A new Information Operations (IO) family has been added along with two new PDUs, the IO Action PDU and IO Report PDU, to support information warfare.
- f) The Electromagnetic Emission PDU has been clarified, and a new jammer field has been added using an existing padding field to better support a wider range of multiresolution simulations.
- g) A new Directed Energy Fire PDU has been added to support high-fidelity directed energy engagements.
- h) A new Entity Damage Status PDU has been added to reflect high-fidelity damage to an entity.

^aInformation on references can be found in Clause 2.

^bThe numbers in brackets correspond to those of the bibliography in Annex J.

- i) The Transfer Control function has been renamed the Transfer Ownership function, and the Transfer Control Request PDU has been retitled the Transfer Ownership PDU. The entire Transfer Ownership function has been revised to improve its functionality.
- j) Transponder and Interrogator requirements have been updated to support high-fidelity Mode 5 Identification Friend or Foe (IFF) and Mode S systems.
- k) Time requirements have been extensively clarified and revised.
- l) Dead reckoning requirements have been updated including the addition of a new quaternion equation. Annex E Dead Reckoning has been completely revised to clarify requirements, although all the existing formulas have been retained.
- m) The Articulation Parameter record found in the Entity State and other PDUs has been renamed the Variable Parameter record to denote that its original design supports more than just its use for articulated and attached parts records. This now provides a way for additional attribute data to be added to entities and detonation characteristics to be added to the Detonation PDU.
- n) A new Attribute PDU has been added to support DIS extensibility.
- o) The Warfare—General requirements subclause (5.4.2) has been rewritten to incorporate the use of the Fire and Detonation PDUs for expendables and the use of the Detonation PDU for non-munition explosions.
- p) The Transmitter PDU was revised to add the capability to have variable Transmitter Parameters records in addition to having a single Modulation Parameters record and multiple Antenna pattern records.
- q) Entity separations have been addressed by clarifying how it is to be done for various situations including for multistage missiles and submunition portrayal.
- r) Seven new annexes have been added as follows:
 - 1) Annex A. Warfare (normative). Provides additional requirements related to PDUs used to support the warfare functional area.
 - 2) Annex B. Specific transponder and interrogator systems (normative). Contains detailed requirements applicable to specific transponder and interrogator systems.
 - 3) Annex C. Radio systems (normative). Contains detailed requirements applicable to specific radio systems.
 - 4) Annex D. Objects (normative). Contains detailed requirements related to object types and primary and secondary identifiers.
 - 5) Annex F. Heartbeats, timeouts, and thresholds (informative). Provides guidance on how to maintain interoperability when some simulations have implemented the new entity timeout requirements and some have not.
 - 6) Annex G. Time calculations and uses (informative). Provides additional information on time and its uses in a distributed simulation environment.
 - 7) Annex H. Transfer ownership function (normative). Contains detailed requirements for transfer ownership.

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IEEE Standard for Distributed Interactive Simulation— Application Protocols

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1 Overview

1.1 General

This standard explains the information technology protocols required for Distributed Interactive Simulation (DIS) applications. This standard is divided into ~~nine~~ ~~five~~ clauses. Clause 1 provides the scope of the standard and details key DIS concepts that will help in understanding the context of this standard. Clause 2 lists references to other standards that are useful in applying this standard. Clause 3 provides definitions of terms, acronyms, and [abbreviations](#) that are used in the standard. It is imperative for the user of this standard to thoroughly review these definitions before proceeding on to the other clauses. Clause 4 contains requirements concerning the content and use of Protocol Data Units (PDUs) in DIS exercises. Clause 5 defines the various PDUs and their fields. [Clause 6 contains requirements concerning the representation of data within the PDUs.](#) [Clause 7 defines the layout and contents of the PDUs.](#) [Clause 8 contains the definition of a protocol specifically for applications operating in non-real time.](#) [Clause 9 is a stand-alone, self-contained clause that contains both the requirements and the PDU definitions for use by live entities participating in a DIS exercise.](#)

1.2 Scope

This standard is part of a ~~proposed~~ set of standards [and recommended practices](#) for DIS applications. Each standard [and recommended practice](#) in the ~~proposed~~ set describes one or more of the elements that constitute the DIS environment. As a whole, the set of standards [and recommended practices](#) defines an interoperable simulation ~~battle~~ environment. This particular standard addresses the application protocols.

1.3 Purpose

This standard defines the data messages, known as PDUs, that are exchanged on a network ~~among~~ ~~between~~ simulation applications. The messages are organized ~~defined~~ are ~~for interactions~~ ~~that take place~~ within specified domains called protocol families. ~~The Current~~ protocol families included in this standard include Entity Information/Interaction, Warfare, Logistics, Simulation Management, Distributed Emission Regeneration, ~~and~~ Radio Communications. Entity Management, Minefield, Synthetic Environment, Simulation Management with Reliability, Information Operations, Live Entity Information/Interaction, and Non-Real Time. Future versions of this standard ~~may~~ ~~will~~ contain additional ~~and~~ protocol families or PDUs to exchange information about interactions and functions not currently supported.

1.4 Terminology

The following terms, which are defined in Clause 3, form the basis for understanding the key concepts stated in 1.6:

- a) ~~Distributed Interactive Simulation~~ DIS
- b) Host computer
- c) Simulation application
- d) Simulation entity
- e) Simulation exercise
- f) Simulation environment

1.5 Conventions used in this document

The following conventions are used in this document:

- a) All numeric values specified in this standard ~~and its annexes~~ are listed in base ten unless otherwise noted by the suffix (H), which denotes a hexadecimal number.
- b) Terms written in all capital letters are symbolic names. The values assigned to the symbolic names are given in 6.1.8.
- c) If a term in italics precedes a PDU name, it is used to more clearly and easily define the use of the PDU.
- d) The names of fields in PDUs and the names of records are capitalized.
- e) All units within PDUs use the International System of Units (SI) (see IEEE/ASTM SI 10™) except when modeling a system that complies with another standard that requires different units.
- f) Enumeration fields have values and descriptions defined in SISO-REF-010. The table for each enumeration is identified by a Unique Identifier (UID) in the form "[UID nnn]". In this standard, references to SISO-REF-010 tables use the same UID syntax; for example, "see [UID 874]".
- g) World coordinate axes are denoted with uppercase X, Y, and Z. Entity (body) and object coordinate axes are denoted with lowercase x, y, and z.

1.6 Key concepts

1.6.1 Introduction

This subclause contains details ~~of~~ ~~on~~ key DIS concepts that will help the reader understand the context of this standard. This information is of a general or an explanatory nature that may be helpful, but it is not mandatory.

1.6.2 Basic architecture concepts

The basic architecture concepts of DIS are an extension of the Simulator Networking (SIMNET) program developed by the Advanced Research Projects Agency (ARPA). The basic architecture concepts for DIS, and their implications as they apply to DIS, are as follows:

- a) No central computer controls the entire simulation exercise. Some simulation systems 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 have to ~~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.

- b) Autonomous simulation applications are responsible for maintaining the state of one or more simulation entities. Simulation applications (or simulations) are autonomous and generally responsible for maintaining the state of at least one entity. In some cases, a simulation application 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 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 for 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.
- c) A standard protocol is used for communicating ground truth data. Each simulation application communicates the state (which is herein called ground truth) of the entity it controls/measures (location, orientation, velocity, articulated parts position, etc.) to other simulations on the network. The receiving simulation is responsible for using ~~taking~~ this ground truth data to ~~and~~ calculate whether the entity represented by the sending simulation is detectable by visual or electronic means. This perceived state of the entity is then presented ~~displayed~~ to the user as required by the individual simulation.
- d) Changes in the state of an entity are communicated by its controlling simulation application.
- e) Perception of events or other entities is determined by the receiving application.

- f) Dead reckoning algorithms are used to reduce communications processing. A method of position/orientation estimation, called dead reckoning, is used to limit the rate at which simulations ~~have to~~ ~~must~~ issue state updates for an entity. Each simulation maintains an internal model of the entity it represents. In addition, the simulation maintains a dead reckoning model of its entity. The dead reckoning 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 internal model of its entity ~~with~~ ~~to~~ the dead reckoning model of the entity. If the difference between the two exceeds a predetermined threshold, the simulation will update the dead reckoning model using the information from the internal model. ~~At the same time,~~ The simulation ~~then also~~ ~~will~~ sends updated information to other simulations on the network so that they can update their dead reckoning model of the entity. By using dead reckoning, simulations are not required to report the status of their entities as often.

1.6.3 Coordinate systems

1.6.3.1 World coordinate system

Locations in the simulated world are identified using a right-handed, geocentric Cartesian coordinate system called the world coordinate system. The shape of the world is described in ~~NIMA DMA~~ TR 8350.2.¹ The origin of the coordinate system is the centroid of the ~~earth~~ [World Geodetic System 1984 \(WGS 84\) reference frame \(ellipsoid\) as defined in NIMA TR 8350.2](#). The axes of this system are labeled X, Y, and Z, with the positive X-axis passing through the prime meridian at the equator, with the positive Y-axis passing through 90° east longitude at the Equator and the positive Z-axis passing through the north pole as shown in Figure 1. A distance of one unit measured in world coordinates corresponds to a distance of 1 m in the simulated world. A straight line in the world coordinate system is a straight line in the simulated world. This is a rotating reference frame that rotates on a daily period as the Earth rotates.

¹~~Information on references can be found in clause 2.~~

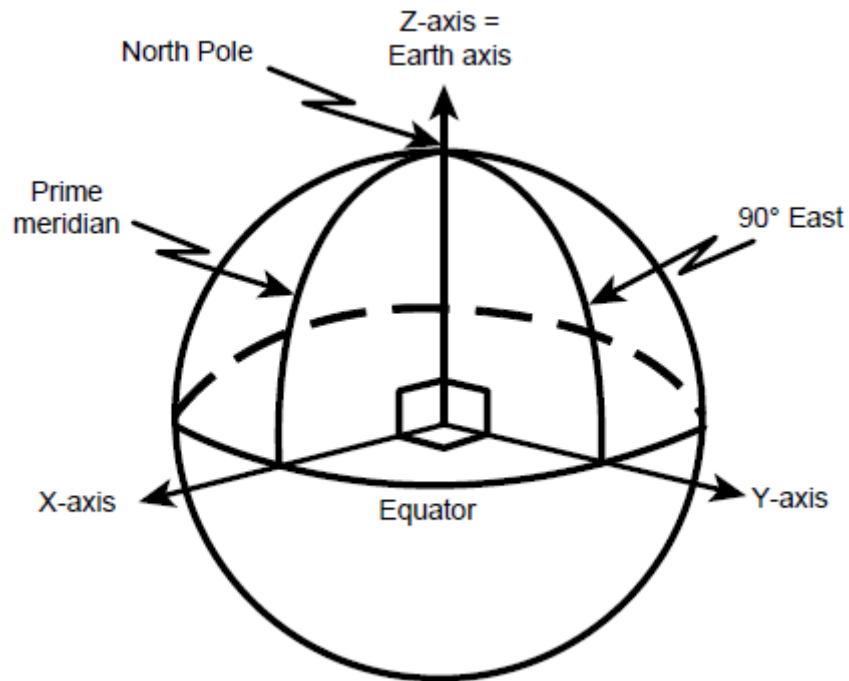


Figure 1—World coordinate system

1.6.3.2 Entity coordinate system

To describe the location and orientation of any particular entity, an entity coordinate system is associated with the entity. This is also a right-handed Cartesian coordinate system with the distance of one unit corresponding to 1 m as in the world coordinate system. The origin of the entity coordinate system is the center of the entity's bounding volume ~~excluding its~~ [The bounding volume of an entity does not include its real-world articulated and attached parts, regardless of whether these parts appear in the Entity State PDU.](#) The axes are labeled x , y , and z with the positive x -axis pointing to the front of the entity, the positive z -axis pointing to the right side of the entity, and the positive z -axis pointing out the bottom of the entity as shown in Figure 2.

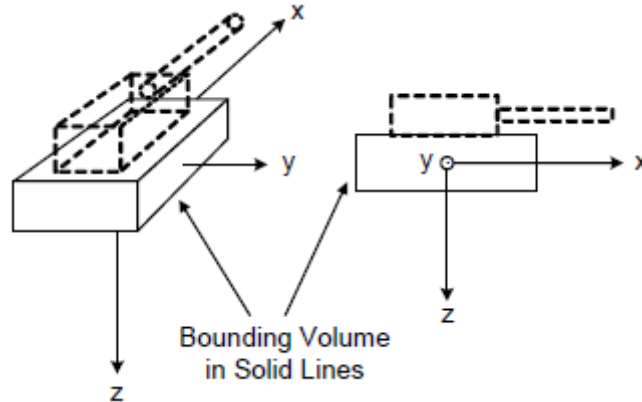


Figure 2—Entity coordinate system

The location of an entity is specified as the position of the origin of its entity coordinate system, expressed in world coordinates. The entity's orientation is specified using three angles that describe the successive rotations needed to transform from the world coordinate system [into](#) the entity coordinate system. These angles are called Euler angles and specify a set of three successive rotations about three different orthogonal axes as shown in Figure 3. The order of rotation is first, rotate about z by the angle ψ (Ψ), then about the new y (y') by angle θ (θ), [and](#) then about the newest x (x'') by the angle ϕ (ϕ). The positive direction of rotation about an axis is defined as clockwise when viewed toward the positive direction along the axis of rotation.

1.6.3.3 Entity velocity and acceleration vectors

[If an entity is moving, its linear velocity is required for dead reckoning. Linear acceleration and/or angular velocity can also be used, if available, to perform a more accurate extrapolation. Velocity and acceleration describe the motion of the entity relative to the rotating Earth, not relative to local effects such as wind or sea currents that can be modeled. For example, the velocity of an aircraft corresponds to ground speed, not to air speed.](#)

Linear velocity and acceleration vectors are transmitted in either world or entity coordinates, depending on the dead reckoning algorithm in use. For linear velocity, the same vector (i.e., the same magnitude and direction from a world view) is represented with either method, only the coordinate axes for defining it are different. For acceleration, however, the centripetal component is removed when converting from world coordinates into body coordinates. For example, an entity turning in a circular path with constant speed has a nonzero, purely centripetal acceleration in world coordinates, but zero acceleration in entity coordinates.

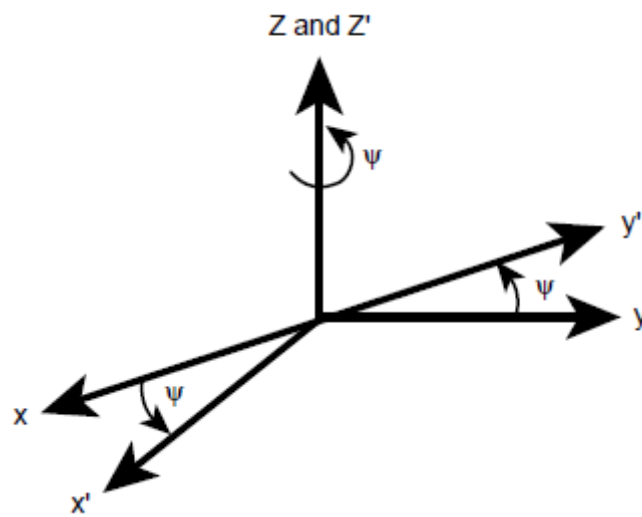
Angular velocity is represented as rotation rates about the entity axes. The rotation rates are generally not the same as Euler angle rates. Instead, angular velocity is a vector $[\omega_x \ \omega_y \ \omega_z]$ in entity coordinates. The vector's direction represents the axis of rotation, and its magnitude $|\omega|$ represents the rate of rotation about that axis. Extrapolation of orientation can be visualized as rotation about the axis at a rate defined by the vector magnitude over a given amount of time.

1.6.3.4 Object coordinate system

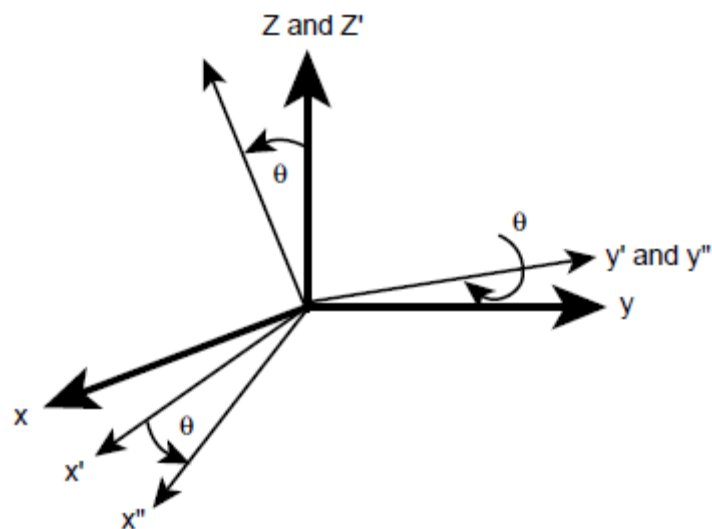
All objects, except as noted below, use the same local coordinate system as described for entities in 1.6.3.2.

1.3.4.1 Current capabilities

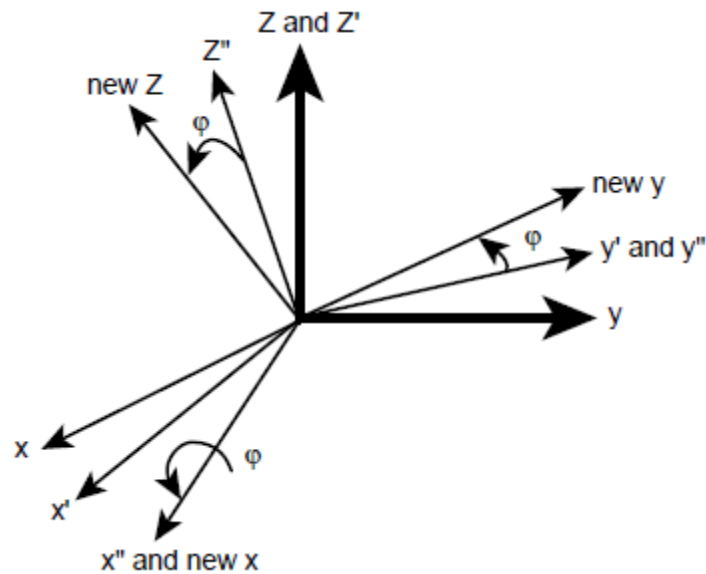
The entity information exchanged between simulation applications includes the type of entity, its location, its orientation, and how the entity might appear to others. The simulation entity could be a vehicle, a building, a munition (such as a missile), or a cloud of smoke. DIS requires that entities be enumerated based on their entity type, allowing a variety of different entities to be represented. Sending the location and orientation of an entity is critical for correct representation of the entity by other simulations on the network. Inclusion of the velocity and the acceleration parameters allows receiving simulations to employ higher-level, higher-accuracy extrapolation routines. See 1.3.1 item f). The visual appearance of an entity can be expressed in a number of ways. Entities may be on fire or smoking, or an entity may emit engine smoke or have a wake trailing behind in the water, or an entity may have entity-specific lights actuated, all of which affect the visual appearance of the entity.



(a) First, rotate about z by angle ψ (Ψ)



(b) Second, rotate about y (y') by theta (θ)



(c) Third, rotate about newest x (x'') by phi (ϕ)

Figure 3—Definition of Euler angles

a) Linear Objects

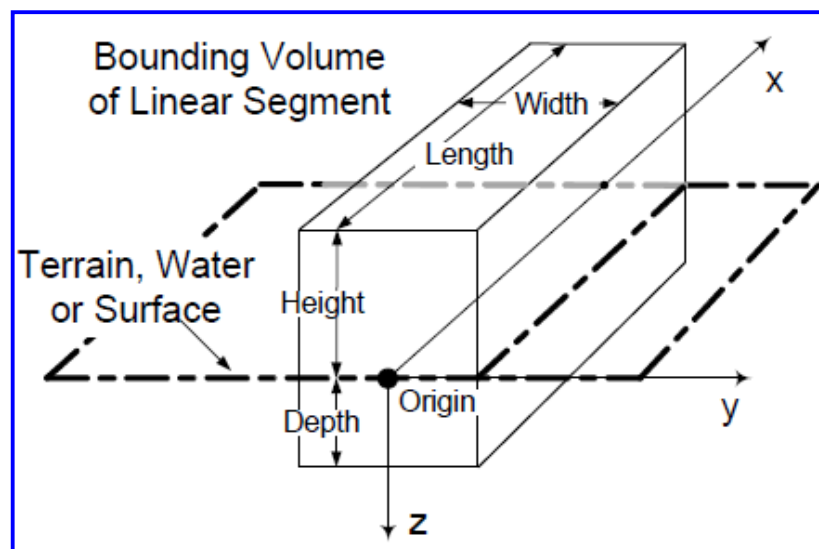
Linear objects as conveyed in the Linear Object State PDU use the same local coordinate system as with entities but have a different origin. There is one origin per segment as specified by the corresponding Segment Location in the Linear Segment Parameter record. As shown in Figure 4, the location of the origin is on one end of the bounding volume and where the object intersects with the terrain, water, or surface upon which it is placed. If a single object origin is required, then the single origin is the origin of the first segment.

b) *Areal Objects*

The location of the points specified for an areal object are where the object intersects with the terrain, water, or surface upon which it is placed.

c) *Ribbon Bridges (Point Objects)*

Ribbon bridges that are point objects and have an Object Type with a Domain of Land (1), Kind of Passageway (4), Category of Ribbon Bridge (3), and any Subcategory, use an origin identical to a linear segment of a linear object.



(New)

Figure 4— Linear object origin

1.6.4 Communication services

The communication services required by each DIS PDU are described in detail in IEEE Std 1278.2-

1995TM

1.6.5 Functional [areas](#) ~~requirements~~ for DIS

DIS ~~is intended to~~ supports the following functional [areas](#) ~~requirements~~:

- Entity Information/Interaction
- Warfare
- Logistics
- [Simulation Management](#)
- Distributed Emission Regeneration
- Radio Communications
- [Entity](#) Management
- [Minefields](#)
- [Synthetic](#) Environment ~~information~~
- [Simulation Management with Reliability](#)
- [Information Operations](#)
- [Non-Real-Time protocol](#)
- [Live Entity Information/Interaction](#)

~~Currently requirements a) through f) are supported by this standard. Enhancement of these areas and the addition of capabilities for area g) are the subject of future standards. A brief description of each is given in 1.3.4.1 and 1.3.4.2.~~

A brief description of each functional area follows:

a) Entity Information/Interaction. The PDUs that provide basic entity and entity collision information are listed under this functional area. An entity is a physical object in the synthetic environment that is created and controlled by a simulation that is affected by the exchange of DIS PDUs. An entity may be a live, virtual, or constructive entity. Examples of entities are as follows: tanks, submarines, ships, aircraft, missiles, buildings, bridges, spacecraft, and life forms such as humans and animals. Information on an entity is sent initially, upon change, and at heartbeat intervals. Such information is designed to support a mixed environment of lower and higher fidelity simulations and visual, aural, and sensor models. A variety of data records allows a specific entity to convey additional attributes needed to support higher fidelity simulations. PDUs can be extended using an attribute message.

~~Throughout a simulation exercise, the state information associated with the interactions that take place between entities needs to be exchanged.~~ Collision Interactions that are currently supported include elastic and in-elastic collisions. ~~If~~ In the event that two entities collide, the simulations controlling the entities have to ~~must~~ be informed of the collision. A message about the collision is sent by each simulation ~~application~~ when it detects that its entity has collided with another entity. Each simulation ~~application~~ determines the damage to its own entity based on information in the collision message. (See 5.3 and 7.2.)

- b) Warfare The PDUs that provide basic warfare information are contained in this functional area. These PDUs support the firing or launch of weapons, including directed energy weapons, the detonation of munitions, the simulation of non-munition explosions, the release of expendables, and the calculation and dissemination of damage effects. ~~Warfare in a DIS exercise involves the firing and detonation of munitions.~~ When an entity fires a weapon or releases an expendable, the simulation application controlling the entity communicates information regarding the fire event that may be needed by other simulations. ~~needs to communicate the location of the firing weapon and the type of munition fired.~~ The detonation of ~~the~~ munitions, non-munitions (e.g., fuel tanks), and expendables is also communicated by the simulation application controlling the munition, explosion, or expendable. Using the information in the detonation message, all simulation applications controlling affected entities assess damage to their entities. Directed energy weapons are supported by conveying detailed characteristics of the energy deposition such as the type of weapon, duration, and beam shape. The effects of weapons fire, collisions, or other sources of damage are communicated in entity damage status messages. (See 5.4, 7.3, and Annex A.)
- c) Logistics. Repair and resupply logistic services are modeled in ~~as a~~ a simulation exercise by means of the logistics ~~family of~~ PDUs. Messages representing requests for services and the transfer of supplies are exchanged between simulations applications that are providers of the repair or resupply service, and those simulated entities in need of such services. (See 5.5 and 7.4.)

- d) *Simulation Management*. PDUs used to manage an exercise and facilitate the operation of the exercise network are contained in the simulation management function. DIS management functions are divided into network management and simulation management. Basic network management functions such as load management, monitoring of nodes and gateways, and error reporting are covered by standard network protocols and tools and are not addressed by the Simulation Management function. Functions of simulation management covered by the Simulation Management function include starting, restarting, pausing, and stopping an exercise; exchanging initialization data; ordering the instantiation and removal of entities; and supporting data collection and dissemination. (See 5.6 and 7.5.)
- e) *Distributed Emission Regeneration*. This functional area supports the simulation of designator lasers; active electromagnetic emitters such as radars and electronic identification and surveillance systems; and active acoustic emissions such as from sonar systems. The messages representing these emission sources are designed to provide sufficient data to allow a receiving sensor simulation to properly detect and interact with the emitter source. The local receiving model recreates the interaction of the system being simulated by using operational parameters in the received PDU along with information from stored databases that describe the system's capabilities. (See 5.7, 7.6, and Annex B.)
- f) *Radio and Intercom Communications*. Audio and digital message communications play an important role in ~~certain types of~~ DIS exercises. The sending (transmitting) entity sends a message defining the details of the communicating device and then the communicated message (voice or digital data). Entities receiving the message can determine their capability to receive the transmitted data and subsequently how to process the received data. Audio communication includes both radio and intercom communications. Tactical data link messages may be conveyed using PDUs in this functional area regardless of which medium is used to send the messages (i.e., a radio, satellite link, a land-based cable, wide area networks, or any other form of communications). (See 5.8, 7.7, and Annex C.)

- g) *Entity Management*. This functional area supports larger DIS exercises by providing mechanisms to allow the aggregation or grouping of entities during an exercise and for the reporting of the state of the group or aggregate in place of the states of the individual entities. Specific protocols are contained in this standard that support these capabilities and the capability to transfer the ownership of an entity from one simulation to another. (See 5.9 and 7.8.)
- h) *Minefields*. The simulation of minefields and individual mines is supported by the PDUs that belong to this functional area. The exchange of information about mines and minefields can be executed in either a heartbeat or a query response mode. (See 5.10 and 7.9.)
- i) *Synthetic Environment*. PDUs within this functional area support the simulation of nonentity synthetic environment objects such as weather, diurnal effects, natural and human-made disturbances (e.g., volcano explosions, earthquakes, and dust and smoke clouds from vehicles or explosions), and terrain-, space-, and water-related environments. This information may include changes to the synthetic environment objects, for instance, the dispersion of chemical clouds over time or changes in terrain by either engineering effects, such as the construction of a bridge or a berm or the destruction of buildings, or by natural effects such as flooding. (See 5.11 and 7.10.)
- j) *Simulation Management with Reliability*. PDUs within this functional area perform the same tasks as the Simulation Management family [see item d)]. In addition, this family specifies mechanisms for reliable communication so that critical management tasks are completed even if individual PDUs are dropped. (See 5.12 and 7.11.)
- k) *Information Operations*. Information Operations (10) supports the interoperability of simulated electronic warfare, computer network operations, military deception, and similar operations used to influence or disrupt enemy decision making. DIS conveys the details of 10 attacks in 10 action messages. 10 Action messages can also contain the predicted effects of an attack. The actual effects of an attack are communicated in 10 report messages. (See 5.13 and 7.12.)

l) *Non-Real-Time Protocol*. Most DIS exercises operate with a human in the loop or have other real-time requirements; therefore, simulation time has to advance at the same rate as real-world time. However, this standard supports other time methods to allow simulation time to advance at a rate other than real-world time. This is accomplished by describing how existing DIS messages can be used to support non-real-time exercises and experiments. (See Clause 8.)

m) *Live Entity Information/Interaction*. PDUs have been developed with a smaller footprint to support live participants using instrumented ranges where there is limited bandwidth. Live entities include life forms such as soldiers, vehicles, aircraft, and ships. DIS is one of several protocols used on instrumented ranges. In some cases, a gateway may convert live participants represented by DIS or other protocols used on a range into regular simulation entities. In this case, DIS supports the identification of a simulated entity as representing a live participant. (See Clause 9.)

~~Representation of lasers, active electromagnetic emissions, and acoustic emissions including active counter measures are essential in certain simulation exercises. Emitting entities simulate their emitter and output real-time operational parameters. Receiving entities can then regenerate the transmitted signal based upon the simulated emitter output data and stored database. Each receiving entity is responsible for determining if the emission is detectable. If detectable, the receiving entity will use the emission data to appropriately influence its detection equipment or simulation of that equipment.~~

Management of a simulation exercise is desirable to facilitate the operation of the network and certain aspects of the simulation exercise. DIS management functions can be divided into network management and simulation management. Network management functions handle the basic network functions such as load management, monitoring of nodes and gateways, and error recovery. The network manager would also have knowledge of host computers on the network, such as their physical locations and network addresses. Analysis of network performance would be performed here. There is also a need for management of the overall simulation exercise. Functions of simulation management include: starting, restarting, pausing, and stopping an exercise; the creation and removal of entities from an exercise; and collection and distribution of data with simulation applications.

1.3.4.2 Future capabilities

A number of capabilities that are not part of this standard are expected to be in future versions of this standard or in related documents.

In addition to visual appearance, an entity may also have a certain infrared signature, or an entity can radiate an acoustic signature that is unique to the entity. Consequently, each entity has several appearances. These include emission of sound, light, and heat, as well as the reflection of light, radar, and sound (sonar).

For simulation 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 to make the exercise as realistic as possible. This information may include changes in the terrain, weather, and ambient illumination. Changes in the terrain can be caused by a number of factors. These include engineering effects such as the construction of a bridge, berm, or a building; weapons effects that could destroy objects created via engineering effects, as well as change the shape of the terrain due to the impact of shells or explosion of mines; or natural effects such as flooding. Conditions such as rain, snow, fog, or clouds need to be represented in DIS to add to the realism of a DIS exercise. The wind and its effect on a cloud of smoke can affect vehicle visibility. Chemical clouds and their dispersal can affect dismounted infantry. Atmospheric conditions can affect radio communications and radar performance between entities. Night battles, as well as day battles, should be simulated. DIS will support battles that can take place in any degree of ambient illumination. The subsurface environment plays a significant role in simulations employing acoustic and seismic sensors and in simulations containing subsurface entities (land mines, submarines, etc.). Oceanographic and geophysical representations will use correlated environment data to simulate these effects where appropriate.

Application protocols supporting field instrumentation applications associated with instrumented live participants are not fully addressed in this standard. Requirements for application protocol suitable for use with real entities on instrumented ranges operating within the DIS environment and interacting with simulated and real entities will be addressed in future versions of this family of DIS standards. Limited communication bandwidth, volume of data, methods of data transmission, and type of data transmitted are among the issues to be addressed.

It may not be necessary that all participants receive all PDUs of an exercise. Mechanisms to allow for efficient use of network resources may include filtering PDUs at various locations in the network, data compression schemes, and sending only changes in the PDU information rather than the entire PDU. Multicast addressing schemes and protocols will be used to create and control groups where PDUs are only sent to members of that group. The multicast mechanisms are currently being developed and will be specified in the areas of communication architecture, network management, and simulation management.

2 Normative references

The following referenced documents are indispensable for the application of this document (i.e., they must be understood and used, so each referenced document is cited in text and its relationship to this document is explained). For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

AIMS 03-1000A, Technical Standard for the ATCRBS/TFF/MARK XIIA Electronic Identification System and Military Implementation of Mode S with Changes 1, 2 and 3, 1 January 2011, DoD International AIMS Program Office, Robins AFB, Georgia.¹

IEEE/ASTM SI 10TM, American National Standard for Metric Practice.² ³

~~This standard shall be used in conjunction with the following publications. When the following standards are superseded by an approved revision, the revision shall apply.~~

IEEE Std 754TM ~~1985 (Reaff 1990)~~, IEEE Standard for ~~Binary~~ Floating-Point Arithmetic~~(ANSI)~~.

IEEE Std 1278.2TM ~~1995~~, IEEE Standard for Distributed Interactive Simulation—Communication Services and Profiles.

¹The latest revision of the AIMS 03-1000A document, and interim changes, is available to authorized U.S. and non-U.S. personnel by contacting the DoD International AIMS Program Office, Robins AFB, Georgia (<https://dod-aims.com/>).

²IEEE publications are available from The Institute of Electrical and Electronics Engineers (<http://standards.ieee.org/>). ASTM publications are available from the American Society for Testing and Materials (<http://www.astm.org/>). ~~445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA~~

³The IEEE standards or products referred to in this clause are trademarks of The Institute of Electrical and Electronics Engineers, Inc.

[International Civil Aviation Organization \(ICAO\) basic Mode Select \(Mode S\) related publications.](#)⁴

- a) [ICAO Doc 9684 AN/951, Manual on the Secondary Surveillance Radar \(SSR\) Systems.](#)
- b) [ICAO Doc. 9688 AN/952 Manual on Mode S Specific Services.](#)
- c) [International Civil Aviation Organization \(ICAO\) Annex 10 to the Convention on International Civil Aviation, Aeronautical Communications, Volume III Communications Systems.](#)
- d) [International Civil Aviation Organization \(ICAO\) Annex 10 to the Convention on International Civil Aviation, Aeronautical Communications, Volume IV Surveillance Radar and Collision Avoidance Systems.](#)

~~IEEE P1278.3 (Draft), Recommended Practice for Distributed Interactive Simulation—Exercise Management and Feedback, June 1990.~~⁴

~~IST-CR 94-37, Standard for Distributed Interactive Simulation—Fidelity Description Requirements.~~⁵

~~IST-CR 95-14, Enumeration and Bit-encoded Values for use with IEEE Std 1278.1-1995, Standard for Distributed Interactive Simulation Application Protocols; minimum compliant version is IST-CR-95-05 with change request 344.~~

⁴The latest edition of ICAO publications is [available from the ICAO Web site \(http://www.icao.int/\)](http://www.icao.int/). Note that ICAO publications may have errata published as separate documents.

~~⁴This IEEE standards project was not approved by the IEEE Standards Board at the time this publication went to press. For information about obtaining a draft, contact the IEEE.~~

~~⁵IST documents are [available from the](#) University of Central Florida, Center for Continuing Education, Orlando, FL, 32816-0177, USA.~~

~~ISO 7498: 1984, Information processing systems—Open Systems Interconnection—Basic Reference Model.⁶~~

ITU-T Recommendation G.711, Pulse Code Modulation (PCM) of Voice Frequencies, ~~in CCITT Blue Book Volume III Fascicle 4, General aspects of digital transmission systems: terminal equipments, 1988.~~⁵

[ITU-T Recommendation G.726, 40, 32, 24, 16 kbit/s Adaptive Differential Pulse Code Modulation \(ADPCM\).](#)

[MTL-STD-188-113, Interoperability and Performance Standards for Analog-to-Digital Conversion Techniques.](#)⁶

[NIMA DMA TR 8350.2, 1987 Third Edition, Amendment 1, 3 January 2000](#), Department of Defense World Geodetic System 1984 (WGS 84), Its Definition and Relationships with Local Geodetic Systems.⁷

~~⁴ISO publications are available from the ISO Central Secretariat, Case Postale 56, 1 rue de Varembe CH 1211, Genève 20, Switzerland/Suisse. ISO publications are also available in the United States from the Sales Department, American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036, USA.~~

~~⁵ITU-T publications are available from the International Telecommunications Union, Sales Section, Place des Nations, CH 1211, Geneva 20, Switzerland/Suisse. They are also available in the United States from the U.S. Department of Commerce, Technology Administration, National Technical Information Service (NTIS), Springfield, VA 22161, USA. (<http://www.itu.int/>).~~

~~⁶This MIL publication is are available from DLA Document Services, Bldg 4/D, Customer Service, Defense Printing Service 700 Robbins Ave, Philadelphia, PA 19111-5094. MIL publications are also available from the U.S. Department of Defense (<http://www.defense.gov/>).~~

~~⁷This publication is available from the National Technical Information Service (NTIS), 5285 Port Royal Road Springfield, VA 22161, USA (<http://www.ntis.gov/>).~~

[SISO-REF-010, Enumerations for Simulation Interoperability. \(SISO-REF-010-00v20-0 or later is required to support this standard. This document is periodically updated.\)⁸](#)

[SISO-STD-002, Standard for Link 16 Simulations.](#)

~~MIL-STD-1821, Military Standard Simulator Data Base (SSDB) Interchange Format (SIF) Design Standard.~~

~~SI, Le Systeme International d'Unites: See for example:~~

- ~~a) — "The Complete Metric System with the International System of Units, (SI)," A.L. LeMaraie and John P. Ciaramella, Abbey Books, 1973.~~
- ~~b) — "Guide for the Use of the International System of Units: The Modernized Metric System," A.O. McCoubrey, Sept. 91, NIST/SP 811. Also available from Supt. of Docs, as SN003-003-03113-5.~~
- ~~c) — "Interpretation of the SI for the United States and Metric Conversion Policy for Federal Agencies," B.N. Taylor, Oct. 91, NIST/SP814. Also available from Supt. of Docs.~~

~~SIMNET, BBN RPT. 7627 The SDV1NET Network and Protocols.⁹~~

⁸[SISO publications are available from the Simulation Interoperability Standards Organization \(SISO\) \(http://www.sisostds.org\).](http://www.sisostds.org)

⁹~~See footnote 2.~~

3 Definitions, special terms, acronyms, and abbreviations

~~This clause contains definitions, acronyms, and abbreviations as they are used in this standard.~~

3.1 Definitions

For the purposes of this document, the following terms and definitions apply. *The IEEE Standards Dictionary Online* should be consulted for terms not defined in this clause.⁹

absolute time: A reference time synchronized across the exercise, which may or may not be Coordinated Universal Time (UTC) time depending on exercise agreements.

absolute timestamp: A timestamp that contains absolute time. Absolute time is signified by the least significant bit being set to one in a timestamp field of a Protocol Data Unit (PDU). See 4.6.3.

acquiring simulation: The simulation application that will become the new owner of the entity involved in a transfer transaction.

active beam: A beam that is producing detectable electromagnetic or acoustic energy.

active emitter: An emitter system with one or more active beams.

aggregate (unit): A group of entities or a group of other aggregates. The substitution of the word "unit" is used to avoid phrases like "aggregate aggregate."

aggregation: The process of changing the resolution of two or more aggregates by replacing them with a single aggregate at a lower level of detail.

⁹The IEEE Standards Dictionary Online subscription is available at http://www.ieee.org/portal/innovate/products/standard/standards_dictionary.html.

areal object: A synthetic environment object that is geometrically anchored to the terrain with a set of at least three points that come to a closure.

application layer (Layer 7): ~~The layer of the OSI reference model (ISO 7498: 1984) that provides the means for simulation applications to access and use the network's communications resources~~

articulated part: A visible part of a simulated entity that ~~may not move relative to the entity, but~~ is able to move relative to the entity ~~itself~~ or relative to another articulated part.

attached part: A visible part of a simulated entity that may not move relative to the entity, but that may or may not be present. For example, a bomb on an aircraft wing station.

attribute: A property or characteristic of an entity, object, or event, for example, antenna location. Also, a property inherent in an entity or object or associated with that entity or object for database purposes.

automatic mode: A simulation is in the automatic mode if the simulation application is automatically processing all messages associated with a transfer transaction. A simulation at which an operator manually initiates a transfer is considered to be in the automatic mode if the operator has no control over the completion of the transfer transaction except to manually cancel the transfer.

ballistic munition: Any munition that follows a ballistic trajectory.

beam: The focused emissions from an electromagnetic or active acoustic transmitter. The beam is defined by the main lobe of the antenna pattern.

NOTE—Beams are also referred to as emitter beams in this standard.¹⁰

¹⁰Notes in text, tables, and figures of a standard are given for information only and do not contain requirements needed to implement this standard.

best effort service: A communication service in which transmitted data is not acknowledged. Such data typically arrives in order, complete and without errors. However, if an error occurs, or a packet is not delivered, nothing is done to correct it (e.g., there is no retransmission).

bit: The smallest unit of information in the binary system of notation.

bit field record: A record whose field structure is defined by explicit bit numbering, not necessarily on octet boundaries.

body coordinates: See: **entity coordinate system.**

constructive: Models and simulations that involve computer-generated entities, their simulated human operators, and other objects that represent life forms, crowds, vehicles, communications, environmental processes, cultural and natural features, terrain, structures, and systems whose behavior and interactions are based on rule sets or other behavioral logic including preplanned activities over a period of simulation time. Real people usually control such simulations and may override programmed actions and outcomes. This extends to real people being able to initiate or take control of an existing constructive entity or process, altering preprogrammed actions and terminating an entity. A typical constructive simulation may generate entities that number in the thousands.

~~**bounding volume:** The six-sided, rectangular enclosing space whose width, length and height are aligned with those of the entity~~

dead reckoning: A method for the estimation of the position/orientation of an entity based on a previously known position/orientation and estimates of the passage of simulation time and motion.

disaggregation: The process of changing the resolution of a single aggregate by replacing it with two or more aggregates at a higher level of detail.

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.

Distributed Interactive Simulation (DIS) gateway: A software application that is not part of a host simulation whose purpose is to affect the transmission, receipt, forwarding, or filtering of DIS Protocol Data Units (PDUs), the modification of PDU content, or which may translate between DIS and some other protocol(s) or associated object models.

divesting simulation: The simulation application that currently owns the entity involved in a transfer transaction.

emitter: A device that is able to discharge detectable electromagnetic, ~~seismic~~, or acoustic energy.

NOTE—Emitters are also referred to as emitter systems in this standard.

emulation data: Data that emulates the characteristics of real-world systems or message content that uses the exact same data format, method, or resolution. This includes data that represents electromagnetic characteristics of a system that would allow emissions to be detected by a physics-based model.

enumeration: A meaning assigned to a numeric value (e.g., 0 = not specified, 1 = normal, 2 = standby, 3 = emergency mode) that is contained in a field or subfield.

entity: *See: simulation entity.*

entity bounding volume: The six-sided rectangular space that minimally enclosed the entity excluding its real-world articulated and attached parts, and whose axes are aligned with the **entity coordinate system**.

entity coordinate system: Aright-handed Cartesian coordinate system, centered at the center of the entity's bounding volume excluding articulated and attached parts, used to define locations of objects with respect to the entity. Also known as body coordinates. See 1.6.3.

entity database: The database(s) used by a simulation to store local entities eligible to be transmitted using the Entity State or Entity State Update PDUs and remote entities derived from those same PDUs.

~~**3.1.12 entity coordinate system :** A system whereby location with respect to a simulation entity is described by an entity coordinate system. See 1.3.2~~

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). See 1.6.3. ~~The order of rotation is first about z by angle psi (—), then about the new y by angle theta (θ), then about the newest x by angle phi (—) (see figure 3). Angles — and — 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.~~

exercise: See: **simulation exercise**.

exercise agreement: An agreement among exercise participants that defines the requirements that have to be met by the participants in support of exercise objectives. These requirements include those that are not covered by standards or other applicable documents, as well as any deviations allowed from those documents. An exercise agreement, as used in this standard, includes any form of agreement among participants, whether written or communicated only verbally.