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# Distributed Simulation Guide


## Australian Defence Simulation Office

Department of Defence, Canberra

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Produced by the Australian Defence Simulation Office in collaboration with the Simulation Hub of the Defence Science & Technology Organisation.

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# Foreword

The Distributed Simulation Guide (DSG) provides a source of initial information and advice in relation to the development and use of Distributed Simulation in support of the nine applications areas cited in Defence Simulation Policy DIG (OPS) 42-1. The Guide also directs the reader to where more detailed information and advice can be found.

The DSG is a living document and will be updated as required given advances in the relevant technology. Comments or further clarification on any aspect of the DSG are welcomed. Please complete the evaluation form at the back of this document and direct to:


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# Amendment List

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# 1 INTRODUCTION

## 1.1 BACKGROUND

1. The Australian Defence Organisation looks increasingly to Simulation as a way to help decision-makers take better account of the complexity, the dynamics and the uncertainties that pervade modern warfare. Combining Simulations into a shared virtual world utilising Distributed Simulation can increase training and decision-making effectiveness by introducing the unpredictability of opposing and supporting forces. Demonstrated examples are the training of US Navy command teams under the US Battle Force Tactical Training (BFTT) program as well as experimentation programs such as Millennium Challenge. This networking combines simulators from within single buildings as well as simulators from multiple locations throughout the world to create realistic, complex, virtual worlds.

2. The Defence Simulation Policy[1] states the Conceptual vision for the combining of Australian Defence simulation systems:

> Simulation support to training extends well beyond the individual; collective training may occur between a few individuals or extended to include large formations or groups, including those from allied nations. The ready availability of economical networks of Simulations means that individuals and groups can regularly interact with each other, to resolve conceptual, doctrinal and procedural differences, to 'socialise' and build trust, and thus to increase their cohesion and effectiveness when conducting real operations. Significantly, Simulation does not replace the fundamental need for exercises and 'live' training activities, but it allows those exercises to focus on high value training evolutions by allowing the preparatory activities to be undertaken, in advance, in virtual environments.

## 1.2 PURPOSE OF THE DISTRIBUTED SIMULATION GUIDE

The purpose of the Guide is to assist the Acquirers, Developers, Managers, Supporters and Users of Simulations in giving an understanding of the concepts of Distributed Simulation technology and to provide guidance on its use in combining Australian Defence Simulations. It also provides guidance on Simulation Interoperability with our allies and coalition partners. The Guide points to more detailed sources of advice and technical information as required.

3. The principle objective of the Guide is captured in the third strategy[2] to achieve the Defence Organisation vision for Simulation:

> **Combine simulations for greater benefit** – As simulation becomes a normal part of the Defence way of doing business certain simulations will be combined to address issues that are broader or at a higher level than one simulation on its own may be able to provide. Through combining simulation practice and outcomes, higher level analysis and collective training to support military options for government will be provided. Note that in this context, simulations may be combined by direct physical link or by some other means of information transfer. Further, the combining of simulations is to be subject to assessment by the same six criteria as are individual simulations.

*Note 1.* *Guidance on addressing the six criteria is contained in the Defence Simulation Proposal Guide. A short extract from this Guide is at Section 3.1.*

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i. [1] DI(G) OPS 42-1 Annex A Para 4.
ii. [2] DI(G) OPS 42-1 Para 27.

4. The purpose of the Distributed Simulation Guide (DSG) is to provide guidance for the combining of Simulations utilising the currently available technologies for Distributed Simulation. In particular, the DSG details key considerations when utilising simulation communication protocols such as the Distributed Interactive Simulation (DIS) and the High Level Architecture (HLA) standards. By applying the guidelines contained within the DSG, Defence and Industry personnel involved with combining Simulations will be assured of operating within a common framework. This Guide offers an introductory overview, and readers are directed to sources of more information and advice in the text as may be required.

5. The DSG is one of the Defence Organisation policy initiatives that will help lead the Simulation community to grow and realise their vision:

**Defence Vision for Simulation**

Defence exploits Simulation
to develop, train for, prepare for and test military options for Government
wherever it can enhance capability, save resources or reduce risk.

# 2 INTRODUCTION TO DISTRIBUTED SIMULATION AND ITS TECHNOLOGIES

## 2.1 INTRODUCTION TO DISTRIBUTED SIMULATION

6. Defence Simulation has historically been confined to single, isolated applications developed solely for a single purpose. This could be to train a pilot to fly a new aircraft or to simulate the trajectory of a missile as it leaves a weapon system and tracks a target through a variety of environmental conditions. The ever increasing advancement of computer based technology has now seen many once isolated systems, connected together to form a complex 'system of systems' world (see Figure 2-1).

7. Computer based Simulation can utilise these same connections to help us to understand, train for and analyse the complexities of modern warfare. It can also represent the real systems and the operational environments they perform in a simplified form that can be more readily understood. These simplified real world representations can then be networked via participating platforms (ie embedded Simulation on planes, ships, tanks), in a single building (such as Maritime HQ), or even a single classroom for joint warfare training.

**Figure 2-1: Distributed Simulation is used to better simulate 'systems of systems'**

8. Every time we wish to build a Simulation[3] to represent a complex activity, it makes sense to first build smaller Simulations to represent individual entities and then to make these smaller Simulations interact with each other to create the desired larger Simulation while spreading the computational load. It also makes sense that if we build Simulations at a later date, then these Simulations can interact with other existing Simulations as required.

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iii. [3] Simulations are composed of five main components: simulation engines/infrastructure which execute the simulation; Models which provide the real world representations; data that provides the essential input to the Models; Visualisation/interaction which displays the results of the simulation; and communication which provides the interfaces between simulations as well as to real world systems.

Distributed Simulation will take many independently constructed Simulations and provide the means to combine them together quickly and cheaply (physically or non-physically) to create a larger, more realistic Simulation (see Figure 2-2).

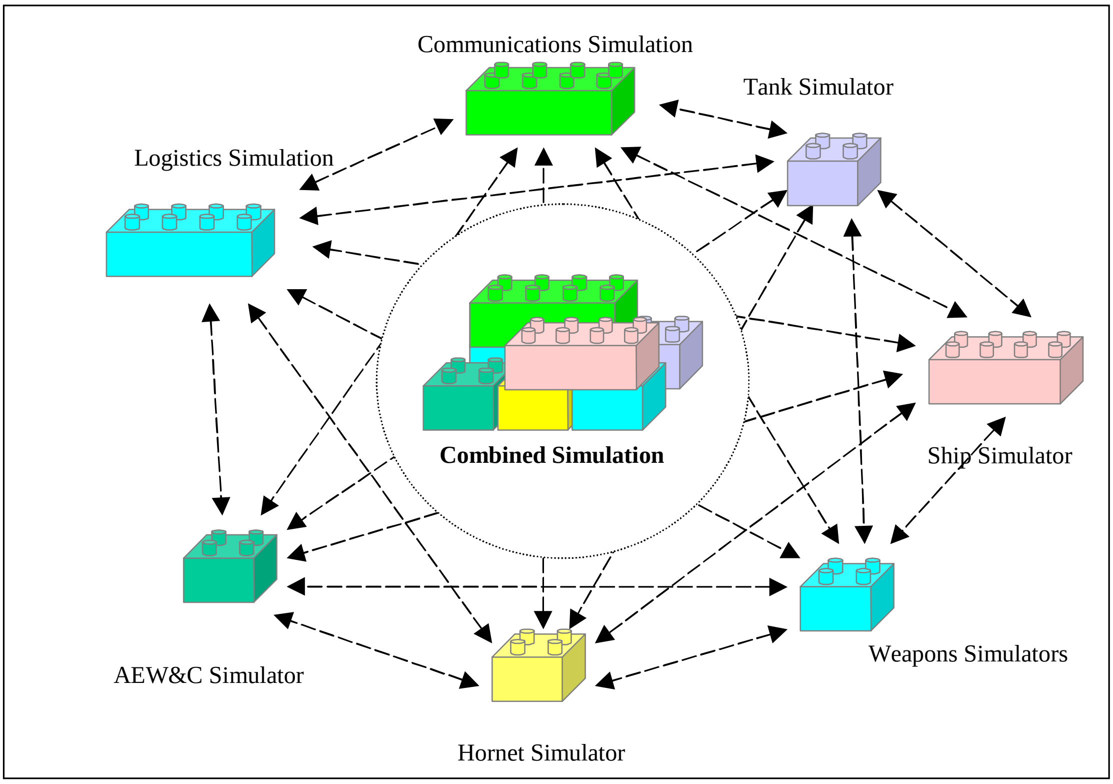


**Figure 2-2: There is a need to combine many smaller Simulations into larger, adaptable Simulations to better represent the real world.**

9. It is important to recognise that the warfighter requires a capability to combine a multitude of individual Simulations into larger Simulations to meet many diverse requirements ranging from planning to mission rehearsal. The key enabler for this to occur is a highly adaptive Simulation Architecture with supporting interfaces and Protocols. There are two Distributed Simulation communication standards that are currently used in Defence to achieve this aim. These are the DIS and HLA standards. These technologies are introduced in Sections 2.2 and 2.3 respectively. An emerging standard based on HLA is the US Test and Training Enabling Architecture and is introduced in Section 2.4.

## 2.2 INTRODUCTION TO DISTRIBUTED INTERACTIVE SIMULATION

10. DIS is a communications standard that provides a method of communicating entity state and other information (such as electronic warfare) by means of message packets called **Protocol Data Units** (PDUs). It evolved from the US Army's SIMNET program[4] in the early 1980's. SIMNET used a set of network Protocols to link many ground vehicle simulators to create a virtual battlespace. DIS is now considered to be a fully mature simulator/Simulation communications technology. It employs a 3D geocentric coordinate system (Figure 2-3) and a standard set of dead reckoning algorithms to reduce the required bandwidth.

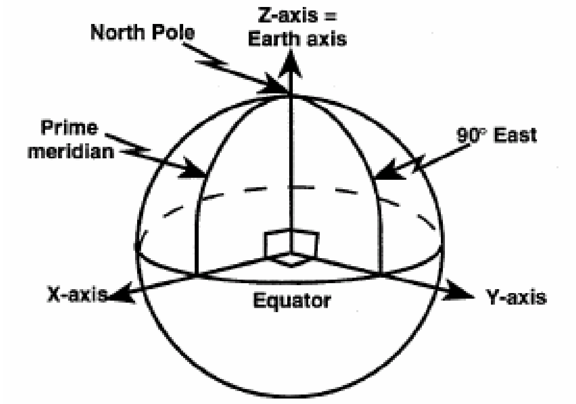


**Figure 2-3: World Coordinate System**[5]

11. Figure 2-4 shows a typical DIS interaction. The FFG (simulator) detects the emissions of the aircraft and sends a Fire PDU. The missile is created within the simulator software and its trajectory is provided by information contained in the Entity State PDUs. When the missile engages the aircraft a Detonation PDU is sent and a damage assessment is made by the simulator (ie simulation) controlling the aircraft.

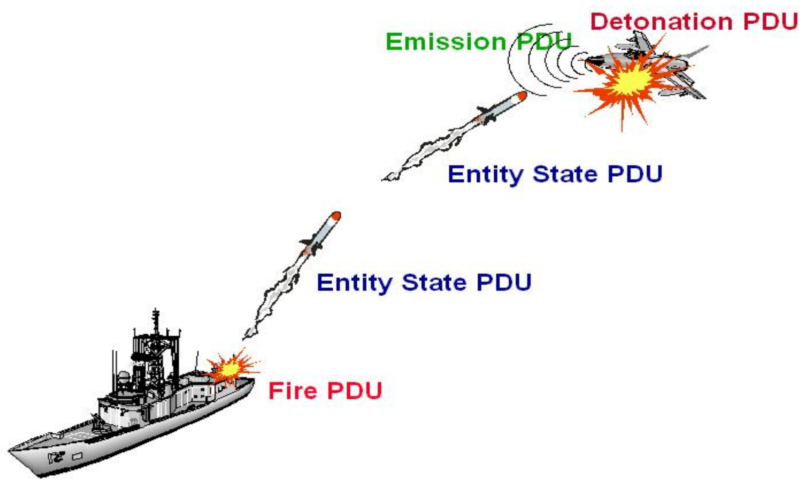


**Figure 2-4: Diagrammatic representation of typical DIS interaction**

iv. [4] An excellent overview of SIMNET and DIS is provided in the August, 1995 IEEE Proceedings Special Issue on DIS.

v. [5] Source: Reference D

### 2.2.1 Distributed interactive simulation standards

12. The Institute of Electrical and Electronics Engineers (IEEE) has approved the DIS standard as IEEE 1278 – 'IEEE Standards for Modeling and Simulation: Distributed Interactive Simulation'. DIS has undergone the IEEE ratification process three times:

a. **IEEE 1278-1993** (1993) that has 10 PDUs to support the appearance and movement of entities, weapons firing, ordnance detonation, collisions, and logistics.

b. **IEEE 1278.1-1995** (1995) that has 27 PDUs with additional support for communications, Simulation management, electronic warfare and laser interactions.

c. **IEEE 1278.1a-1998** (1998) that has 67 PDUs with additional support for emissions, entity information/interaction, underwater and mine warfare, entity management, field instrumentation, communications and environment.

13. With each revision, the approach has been to add new capability via new PDUs with minimal changes to existing PDU structures. Thus an Entity State PDU in IEEE 1278.1a-1998 is identical to an Entity State PDU in IEEE 1278.1-1995, except for the field specifying the applicable DIS version.

14. There are also various draft versions – **DIS 2.0.4** was the draft that evolved into IEEE 1278.1-1995 and **DIS 2.1.4** the draft for IEEE 1278.1a-1998. These draft and IEEE standards are sometimes referred to by **DIS version numbers** as outlined in Table 2-1.

*Note 2. These numbers equate to the DIS protocol version enumeration bit number.*

**Table 2-1: DIS versions**

| | |
|---|---|
| ***DIS version 1*** | DIS PDU version 1.0 (May 1992) |
| ***DIS version 2*** | IEEE 1278 – 1993 |
| ***DIS version 3*** | DIS 2.03 (3rd draft dated May 1993) |
| ***DIS version 4*** | DIS 2.04 ($4^{th}$ draft dated March 1994) |
| ***DIS version 5*** | IEEE 1278.1 – 1995 |
| ***DIS version 6*** | IEEE 1278.1a – 1998 |

15. IEEE 1278.1a-1998 is the current recognised version of DIS and includes four approved specifications. These are:

a. 1278.1a-1998 Application Protocols

b. 1278.2-1995 Communication Services and Profiles

c. 1278.3-1996 Exercise Management and Feedback, and

d. 1278.4-1997 Verification, Validation, and Accreditation

*Note 3. The IEEE 1278.1a standard is a standalone standard that refers to a new set of DIS PDUs including those covered by the IEEE 1278.1 standard. However the IEEE 1278.1 a* *standard documentation does not include information on the DIS PDUs covered by the IEEE 1278. standard. The IEEE 1278.1a standard documentation is an incremental documentation upgrade and relies on the user also having the IEEE 1278.1 documentation.*

16. Some programs, such as the US BFTT, FFG Upgrade project and AP-3C project have created PDUs additional to the IEEE 1278.1a-1998 specification to meet their own particular Simulation requirements[6]. As a result, the Australian Defence Simulation Office (ADSO) and the Defence Science & Technology Organisation (DSTO) have been seeking agreement to establish a new IEEE standard to include these additional PDUs.[7]

ADSO recommends as a minimum that the IEEE 1278.1a-1998 specification is used for all DIS based Australian applications.

*Note 4.* *Additional PDUs to the IEEE 1278.1a-1998 set may not be interoperable with other simulators and will need careful management by those concerned.*

17. The above standards are supported by **Enumeration** sets contained within a document titled, 'Enumeration and Bit Encoded Values for Use with Protocols for Distributed Interactive Simulation Applications'. This document provides a comprehensive standard set of enumerations for entities, weapons, sensors, communication devices, environmental descriptors and other attributes. Enumerations provide the numerical values and associated definitions for those DIS PDU fields that are identified as enumerations in the IEEE 1278 standards. DIS enumerations are available from the Simulation Interoperability Standards Organisation (SISO) website (http://www.sisostds.org/) and explained more fully in Section 6.1.2. Documentation on the IEEE DIS Protocols is also available from the SISO website. As an example of a typical PDU structure, Table 2-2 shows the Fire PDU and the fields required to be populated.

18. A new version of the IEEE DIS Standard to be known as IEEE P1278.1 is due to be released during 2005. IEEE P1278.1 is mainly aimed at cleaning up interpretation ambiguities (see Note 14) and previous IEEE 1278.1 and IEEE 1278.1a documentation sets are to be combined into the one, single standard document (see Note 3).

vi. [6] Refer to Annex E

vii. [7] SISO, recognising that DIS is still an active standard, has formed a DIS Study Group (May 2003). This group has a charter of examining the current standard for incompleteness and inconsistencies. It may seek to update the standard if there is sufficient user support.

**Table 2-2: Fire PDU[8]**

| Field size (bits) | Fire PDU Fields | |
|---|---|---|
| 96 | PDU Header | Protocol Version—8-bit enumeration |
| | | Exercise ID—8-bit unsigned integer |
| | | PDU Type—8-bit enumeration |
| | | Protocol Family—8-bit enumeration |
| | | Timestamp—32-bit unsigned integer |
| | | Length—16-bit unsigned integer |
| | | Padding—16 bits unused |
| 48 | Firing Entity ID | Site—16-bit unsigned integer |
| | | Application—16-bit unsigned integer |
| | | Entity—16-bit unsigned integer |
| 48 | Target Entity ID | Site—16-bit unsigned integer |
| | | Application—16-bit unsigned integer |
| | | Entity—16-bit unsigned integer |
| 48 | Munition ID | Site—16-bit unsigned integer |
| | | Application—16-bit unsigned integer |
| | | Entity—16-bit unsigned integer |
| 48 | Event ID | Site—16-bit unsigned integer |
| | | Application—16-bit unsigned integer |
| | | Event Number—16-bit unsigned integer |
| 32 | Fire Mission Index | 32-bit unsigned integer |
| 192 | Location in World Coordinates | *X*-component—64-bit floating point |
| | | *Y*-component—64-bit floating point |
| | | *Z*-component—64-bit floating point |
| 128 | Burst Descriptor | Munition—64-bit Entity Type record |
| | | Warhead—16-bit enumeration |
| | | Fuse—16-bit enumeration |
| | | Quantity—16-bit unsigned integer |
| | | Rate—16-bit unsigned integer |
| 96 | Velocity | *X*-component—32-bit floating point |
| | | *Y*-component—32-bit floating point |
| | | *Z*-component—32-bit floating point |
| 32 | Range | 32-bit floating point |
| Total Fire PDU size = 768 bits | | |

## 2.2.2 Infrastructure and support

19. As DIS provides a standard means for interconnecting simulators, many tools have been developed such as scenario generators, viewers, data loggers, and analysis toolkits. These are explained further at Section 6.2.

20. DIS requires a network of suitable Necessary Bandwidth and Latency. A closely coupled DIS exercise (eg one with fast jets engaging within visual range) must have Latency of less than 100 ms, whereas a loosely coupled DIS exercise must have Latency of less than 300 ms).

viii. [8] Source: Reference D

21. A DIS Test Suite (DTS) has been developed to test DIS Compliance of Simulation systems prior to their participation in DIS exercises. The DTS supports DIS versions 6 and below and runs under Windows and Linux. The DTS is further explained at Section 9.1.

### 2.2.3 Advantages and disadvantages of distributed interactive simulation

22. The advantages of using DIS are as follows:

a. DIS is a mature simulation protocol and provides an IEEE standardised means of interconnecting simulators. PDU data structures, and usage rates, are defined within the IEEE specification.

b. IEEE standardisation allows for the availability of Commercial-Off-The Shelf (COTS) DIS software applications such as scenario generators, 2D and 3D viewers, data loggers, and analysis toolkits.

c. DIS provides a standard set of enumerations for entities and also for weapons, sensors, communication systems, environmental descriptors and other attributes. Compliance with those enumerations is mandatory for participation in a DIS exercise.

d. DIS specifies a standard set of dead reckoning algorithms that can be used to reduce network traffic.

23. DIS has the following disadvantages:

a. Functionality has been added to DIS by creating new PDUs rather than by redesigning its Architecture. The format and the data contained within DIS PDUs are defined by the relevant IEEE standards. Although much of the data within these PDUs may be redundant, there is no scope to reduce the PDU size. This can result in high computational requirements and network Necessary Bandwidth for large scale networked systems.

b. DIS is designed principally for linking real-time, platform level systems such as manned flight simulators. It does have some non-real time capability, however for practical reasons is used by DIS practitioners.

c. DIS has limited support for entity aggregation and deaggregation.

d. DIS may lack a basic level of security because PDUs are a published standard – any participant can eavesdrop the exercise on the network.

e. In the past, IEEE DIS standard updates have been slow resulting in variations to allow for new functionality that is not accommodated by the Standard.

f. Simulators that use different versions of the DIS standard or implement PDUs within the same standard differently may not be interoperable.

g. DIS broadcasts data to all participants in a DIS exercise, regardless of whether the information is required or not.

## 2.3 INTRODUCTION TO THE HIGH LEVEL ARCHITECTURE

24. HLA is a methodology designed to support the combining of Simulations to allow the conduct of Distributed Simulation exercises. HLA is foremost a software Architecture and is defined not by software but by a set of documents. A general description of the purpose behind the development of HLA is obtained from the US Defense Modeling and Simulation Office (DMSO) website (https://www.dmso.mil/public/):

> The Department of Defense (DoD) Modeling and Simulation (M&S) Master Plan calls for the establishment of a common high-level simulation architecture to facilitate the Interoperability of all types of Models and simulations including C4I systems, and to facilitate the reuse of simulation components. The HLA, developed in response to the Master Plan, provides a systematic and consistent basis for addressing simulation system design and implementation issues, facilitates Interoperability and reuse through a set of common rules, and furnishes a framework for making policy decisions.

25. The HLA designers had the followed five goals (Reference M):

a. It should be possible to decompose a large Simulation problem into smaller parts. Smaller parts are easier to define, build correctly, and verify.

b. It should be possible to combine the resulting smaller Simulations into a larger Simulation system.

c. It should be possible to combine the smaller Simulations with other, perhaps unanticipated Simulations to form a new system.

d. Those functions that are generic to component-based Simulation systems should be separated from specific Simulations. The resulting generic infrastructure should be reusable from one Simulation system to the next.

e. The interface between Simulations and generic infrastructure should insulate the Simulations from changes in technology used to implement the infrastructure, and insulate the infrastructure from technology in the Simulations.

26. HLA is defined by:

a. the **Rules** that specify how Simulations interact, the design principles and responsibilities; and

b. the **Run Time Infrastructure** (RTI) that provides the means to exchange data during execution (a software program analogous to a telephone exchange or computer bus).

27. In HLA terminology, each component software Simulation is called a **Federate**[9] and a set of participating Federates and the RTI (or the combined Simulation system) is known as a **Federation**. All data for the simulation is stored within each Federate. Where DIS requires Compliance to a standard PDU set, HLA allows each Federate to specify what information it will generate (and in what format) and what data it receives. It is through this common

ix. [9] A Federate may take the form of an aircraft wing or missile or it may take the form of a complete squadron. The level of aggregation of Federates is determined by the developer to meet the required need. A Federate is also the unit of software reuse.

interpretation of shared data that the Federates interact within a single virtual environment. Figure 2-5 shows a representation of a HLA Simulation involving three Federations (Aerospace, Land, and Maritime) contained in one larger Federation (ADF).

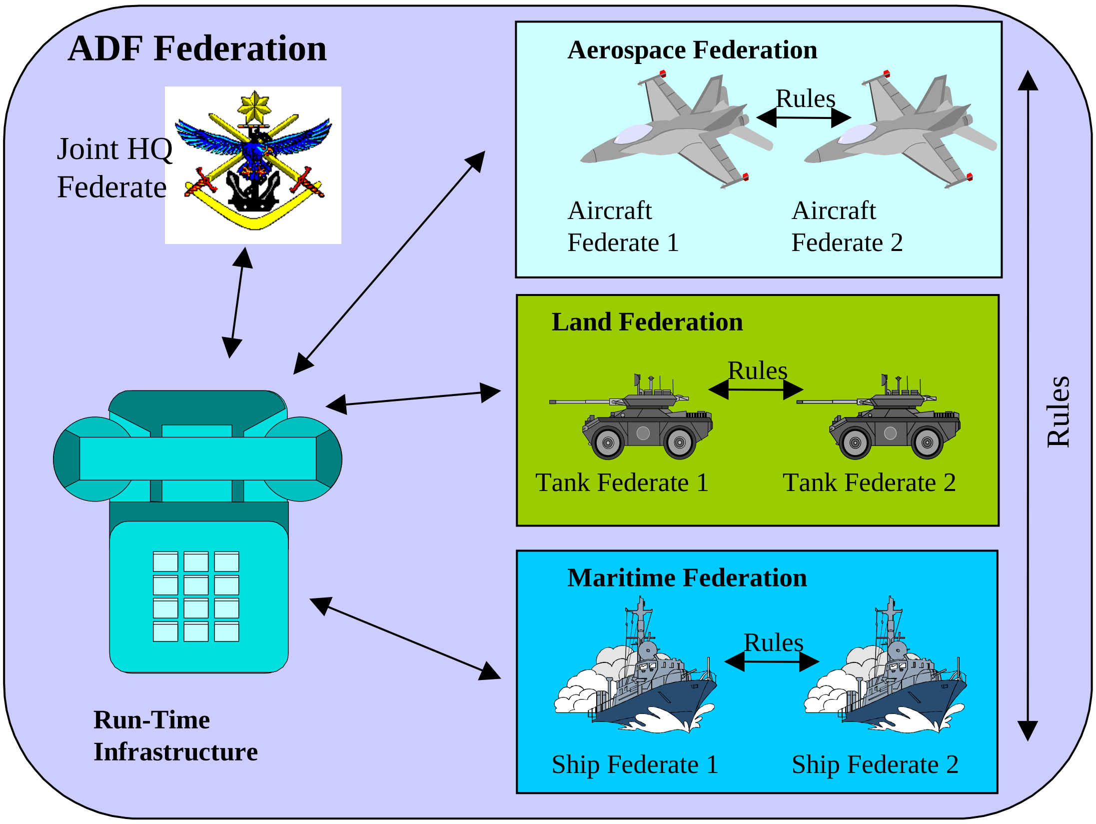


**Figure 2-5: Representation of High Level Architecture software component Interactions**

*Note 5.* *An RTI can support more than one Federation at the one time.*

28. Each Federate must have an associated **Simulation Object Model** (SOM) which describes its data requirements for modelling each component Simulation entity. The SOM has a tabular format with an object class structure table and an interaction class structure table. **Object classes** typically refer to simulated physical entities such as aircraft and ships while **interaction classes** describe the entity actions and interactions such as weapon fire and communications.

29. To form a Federation, a **Federation Object Model** (FOM) is developed to describe the data exchanged between Federates in a **Federation Execution** (or session of a Federation executing together). The FOM is an important tool for communicating design decisions between the Federate and Federation Developers. The FOM has the same structure as the SOM and identifies the attributes and interactions supported by the Federation. All participating Federates must use the same FOM.

### 2.3.1 The high level architecture standard

30. There are currently two HLA standards currently in use. The first is the original DMSO HLA standard Version 1.3 or HLA V1.3. It consists of:

a. High Level Architecture Rules, Version 1.3, U.S. Department of Defence, April 1998.

b. High Level Architecture Interface Specification, Version 1.3, U.S. Department of Defense, April 1998.

c. High-Level Architecture Object Model Template (OMT) Specification, Version 1.3, U.S. Department of Defence, April 1998.

The latest version of the standard is V1.3 New Generation 6. However, due to shortfalls in this version and its predecessor, it is recommended that if the developer identifies a need to use HLA V1.3 (Note: Interoperability and support issues need to be thoroughly considered) then V1.3NG4 should be used. The HLA V1.3 standard will not be further developed by DMSO, but is still supported by commercial vendors. However, DMSO will continue to retain an interest and support of those aspects of the HLA program that are not commercially viable or could impact the US Defence goals of achieving Interoperability and reuse among simulation components (ie RTI verification, HLA certification and resource repositories). The HLA V1.3 standard is available from DMSO from www.dmso.mil. DMSO ceased distribution and support of the DMSO RTI for HLA V1.3 in October, 2002. RTI's for HLA V1.3 are now developed and supported by commercial vendors – see Annex E.

31. DMSO submitted HLA V1.3 to the IEEE for approval as an IEEE standard. The IEEE subsequently (with some improvements) approved it as an open standard in September 2000. It is called 'IEEE 1516 - IEEE Standard for Modeling and Simulation (M&S): High Level Architecture (HLA)' and its components are listed below:

a. **1516 - 2000 Framework and Rules**: The HLA rules are principles and conventions that must be followed to achieve proper interaction of Federates during a Federation Execution. They describe the responsibilities of Federates (Simulations, supporting utilities, or interfaces to live systems) and Federations (sets of Federates working together to support distributed applications). The rules comprise a set of underlying technical principles for HLA. For Federations, the rules address the requirement for a FOM, object ownership and representation, and data exchange. For Federates, the rules require a SOM, time management in accordance with the HLA RTI time management services, and certain mandatory functionality and constraints on attribute ownership and updates.

b. **1516.1 - 2000 Federate Interface Specification**: In HLA, Federates interact with a RTI (analogous to a special-purpose distributed operating system) to establish and maintain a Federation and to support efficient information exchange among Simulations and other Federates. The HLA interface specification is the specification of the interface between Federates and the RTI.

c. **1516.2 - 2000 Object Model Template (OMT) Specification**: HLA requires Simulations (and other Federates) and Federations to each have an object model describing the entities represented in the Simulations and the data to be exchanged across the Federation. The HLA OMT prescribes the method for recording the information in the object models, to include objects, attributes, interactions, and parameters, but it does not define the specific data (eg vehicles, unit types) that will appear in the object models. The OMT is the meta-model for all FOMs.

d. **1516.3 – 2003 Recommended Practice for High Level Architecture (HLA) Federation Development and Execution Process (FEDEP)**: This recommended practice describes a high-level process by which HLA Federations can be developed and executed to meet the needs of a Federation User or sponsor. It is not intended to replace low-level management and systems engineering practices native to HLA User organisations, but is rather intended as a higher-level framework into which such practices can be integrated and tailored for specific uses.

32. The components of the HLA standard are represented in Figure 2-6. IEEE 1516 is available for purchase at http://standards.ieee.org/. SISO is responsible for the development of IEEE 1516 and further information can be found at http://www.sisostds.org/.

As commercial vendors are now in a position to support IEEE 1516 (2000), it is recommended that IEEE 1516 be adopted for future Australian HLA applications.

*Note 6. Currently both Pitch and MaK produce IEEE 1516 compliant RTIs - see Annex E. However, further commercial products should be compliant in the future. In the near term, developers should consider the value for money options of the two standards, noting that the DMSO standard will be phased out.*

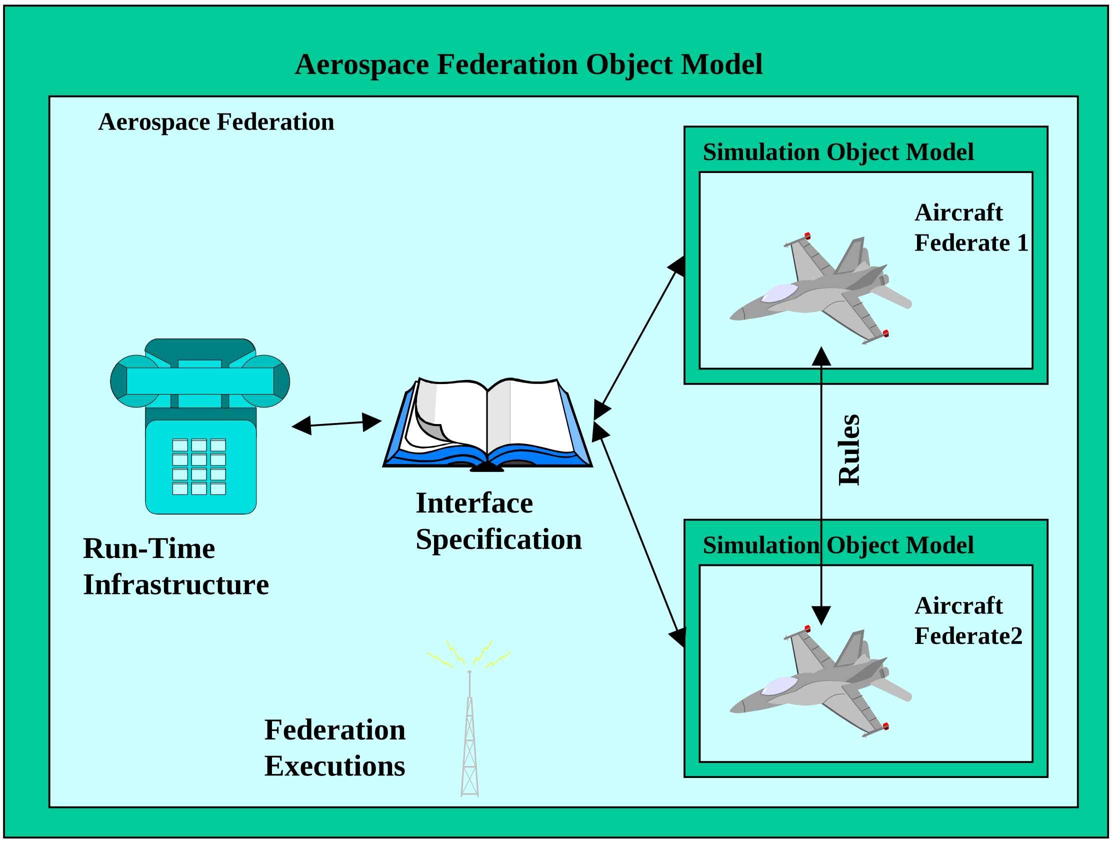


**Figure 2-6: Representation of a typical HLA Standard Implementation**

33. The need for reference FOMs has been proposed to assist with conversion of DIS systems to HLA and to further promote Interoperability. The **Real-Time Platform Reference FOM** (RPR FOM) has been developed for Real-Time platform level Federations to facilitate the transition for DIS compatible Simulations to HLA. The RPR FOM is also a SISO

standard. Note that RPR FOM 1.0 provides the functionality of IEEE 1278.1-1995. RPR FOM 2.0 provides the functionality of IEEE 1278.1a-1998. There are plans to develop a RPR FOM 3.0 at a later stage. Further detailed discussion on RPR FOMs is at Section 3.6.1.

*Note 7.* *A* **Base Object Model (BOM)** *is a type of reference FOM. A BOM is like a subset of a FOM or a SOM. It is a re-useable HLA component that other FOMs/SOMs can be made up of. Refer to Section 7.1.3.3 for further information.*

### 2.3.2 New Versions of HLA - IEEE P1516, IEEE P15161.1 and IEEE P1516.2

34. The IEEE 1516 standards IEEE 1516, IEEE 1516.1 and IEEE 1516.2 are currently being updated/revised and are due to be released as new IEEE P1516, IEEE P1516.1 and IEEE P1516.2 standards during 2005. These updated 2005 IEEE 1516P series standards will be augmented to reflect evolving user needs and advances in technology, such as the SISO HLA Evolved work, to allow greater interoperability and reuse across simulation classes, and ensure consistency within the 1516 series.

35. Some typical new SISO HLA Evolved concepts likely to be incorporated into the 2005 IEEE 1516P series standards include RTI Dynamic Link Capability compliance, RTI Dynamic Link Capability accreditation, removal of unused RTI service components, etc.

### 2.3.3 Infrastructure and support

36. HLA requires a RTI to interface with the Federate Simulation software. DMSO ceased distribution and support of the DMSO RTI in October, 2002. Other versions are available on a commercial basis. DSTO should be consulted by Developers on the choice of RTI for particular applications. See Annex E for further information

37. HLA requires a network of less Necessary Bandwidth than DIS, however Latency is still an issue.

38. A package called SIMplicity has been developed by Calytrix[10], with the assistance of ADSO and DSTO, to help build HLA Simulations quickly without a involving high degree of technical knowledge. DSTO has also developed a package called DSILI to support the Interoperability (or **FOM Agility**) of differently built Simulations without any modification of the simulator source code. A comprehensive set of tools to support Federation development and execution is also available from the DMSO. These tools are further explained at Section 7.2.

39. The DMSO HLA cell will test the Compliance of HLA Simulations to US utilised standards in the near term until Australia has formulated its own Compliance Process (see Section 9.2).

### 2.3.4 Advantages and disadvantages of the high level architecture

40. The advantages of HLA are as follows:

a. HLA Federation members must define in advance what data need to be sent to the network via its publish/subscribe mechanism. HLA can thus reduce the Necessary Bandwidth, since only the required data is transmitted. Further bandwidth

x. [10] Calytrix is an Australian company based in Perth. Further information on Calytrix or its products can be found at http://www.calytrix.com/.

reductions can be achieved since Users can select when attributes should be updated.

b. HLA can provide greater functionality than DIS – any attribute can be dead reckoned and any logical coordinate system can be used instead of the 3D DIS geocentric system (see Figure 2-3).

c. HLA supports both Real-Time and logical time management.

d. Since data broadcast is FOM-specific, HLA provides a basic level of security: interested parties will have difficulty interpreting the data on the network without knowledge of the FOM data content and formats.

e. HLA operates independently from new software developments and networking technology.

41. HLA's disadvantages are as follows:

a. HLA's flexibility can also be its weakness: unless all Federates agree on a FOM they will not be able to interoperate without the use of tools such as SIMplicity and DSILI. Thus HLA Compliance will not guarantee Interoperability where two different FOMs (or their components) are utilised within the same simulation.

b. Different versions of the RTI are incompatible and are now only available and supported commercially. Careful selection is required to obtain the most appropriate RTI for the particular application (Note: Open RTIs are currently being developed. ADSO and DSTO will also investigate suitable RTI/s for Australian wide adoption).

c. There is currently no standardisation of RTI-to-RTI communication protocol. Everyone in a particular simulation must use the same RTI.

d. Each FOM needs its own separate set of enumerations which are provided as standard in DIS. Dead reckoning algorithms must be developed as required instead of using the standard DIS set. Moreover, since each FOM will be unique, FOM-specific viewers, loggers, analysis toolkits, and after action review toolkits, may need to be configured and maintained.

e. HLA Compliance testing involves testing against one's own system (or FOM) – the *only system* guaranteed to be interoperable.

## 2.4 INTRODUCTION TO THE TEST AND TRAINING ENABLING ARCHITECTURE

42. The US military uses Open Air Ranges, System Test Facilities, System Integration Laboratories, Hardware-In-The-Loop Facilities, and Modelling and Simulation Centres throughout the world to test new platforms and concepts. Some of these test ranges also operate as training ranges. These ranges have, over time, been developed as "stovepipe" systems, built with different (non-interoperable) suites of sensors, networks, hardware, and software. Testing and training of modern, sophisticated and complex military systems is becoming more difficult and expensive and will require the integration of systems from

multiple ranges with hardware-in-the-loop-facilities and advanced simulations. To overcome this "stovepipe" structure and to encourage interoperability, reuse and composability, the Test and Training Enabling Architecture (TENA) is being progressively introduced. TENA documentation is available from the TENA web site at www.fi2010.org/index.php.

43. TENA is a product of the US Foundation Initiative 2010 (FI 2010) project. The FI 2010 project performed numerous studies on other architectures, including the US Defense Information Infrastructure Common Operating Environment (DII COE) and the High-level Architecture for Modelling and Simulation (HLA). TENA builds upon the advances made by each of these architectures.

44. TENA promotes integrated testing and simulation supported acquisition through the use of the concept of a Synthetic Range where real military assets, such as ships, aircraft, or ground vehicles, can interact with each other and with simulated weapons and forces, no matter where these forces actually are throughout the world. These Synthetic Range components can be rapidly constructed (ie composed) into a working system to meet a given mission or set of missions.

45. In a Synthetic Range the entirety of the test and training event is represented in the virtual world, while only a part of the event is represented in the real world on the Range Environment. Live assets are projected into the virtual world along with simulated assets. Interactions between assets occur both in the real world and the virtual world. The virtual world consists of a representation of the natural environment, a well-defined set of objects that populate and evolve in that environment, and a communication mechanism to make sure that all interactions between assets occur in a managed and time-consistent fashion.

46. A Synthetic Range is a union of two basic concepts, that of a logical range and a virtual environment. A logical range integrates testing, training, simulation, high performance computing technologies, distributed across many facilities, and ties them together with a common architecture. A logical range is a range without geographic boundaries. The virtual environment can be created by a suite of simulations or by a single simulation.

47. The core of TENA is the TENA Common Infrastructure, including the TENA Middleware, the TENA Repository, and the TENA Logical Range Data Archive. TENA also specifies the existence of a number of tools and utilities, including those necessary for the efficient creation of a logical range. Range instrumentation systems (also called range resource applications) and all of the tools interact with the common infrastructure through the medium of the TENA object model. The TENA object model encodes all of the information that is transferred between systems during a range event. It is the common language with which all TENA applications communicate.

### 2.4.1 An overview of the TENA architecture

48. The limitations of the test and training range stovepipe paradigms, architectures, and protocols have been recognised and a TENA common test and training range architecture, specific to the test and training range domain, is being developed. An overview of the TENA architecture is shown in Figure 2-7.

49. TENA recognizes five basic categories of software, distinguished by color in Figure 2-7:

a. **TENA Applications (Range Resource Applications and TENA Tools) (green) –** Range Resource Applications are range instrumentation or processing systems built to be compliant with TENA and are the heart of any logical range. They are created by range developers and deployed on each range to perform all of the important functions needed for everyday testing and training. These include display systems, sensor systems, hardware-in-the-loop test-beds, and others. TENA Tools are generally reusable TENA applications that help facilitate the management of a logical range through the entire range event lifecycle. They are designed to help logical range developers and event planners manage aspects of planning, executing, managing, and analysing a logical range execution. All of these applications communicate using a common software infrastructure called the TENA Middleware.

b. **Non-TENA Applications (gray) –** are range instrumentation/processing systems, systems-under-test, simulations, and C4ISR systems not built in accordance with TENA but needed in a logical range. TENA Gateways enable interoperability between compliant TENA applications and applications that are not TENA compliant. Such Gateways are responsible for performing translations required between the TENA objects used in a logical range and other standards and protocols used by non-TENA systems (eg TENA/HLA or TENA/DIS Gateways).

c. **The TENA Common Infrastructure (red) –** are sub-systems that provide the functionality necessary to enable interoperability during the entire TENA event lifecycle. These include

   i. the **TENA Repository**, contains all information that is not specific to a given logical range and is intended to be reused between logical ranges. It could contain the TENA Object Model, the executables of TENA utilities and tools, the object code and libraries of the TENA Middleware infrastructure software, TENA documentation, lessons learned and other information necessary for the TENA mission;

   ii. the **TENA Middleware**, for real-time information exchange, that is all run-time inter-application communication in a Logical Range between objects defined in each logical range's Logical Range Object Model (LROM). Many of these objects are reused (created) from the standard TENA Object Model. Range Resource Applications, tools, and utilities exchange information between each other using the TENA Middleware real-time, low latency communications infrastructure. The TENA Middleware toolkit includes an Application Programmer's Interface (API) that supports a set of real-time data exchange services. These services enable range system developers to manage LROM objects, manage the logical range, provide callbacks from the Middleware software into range resource applications, provide services to enable TENA applications to publish and subscribe data such as software objects, messages and data streams (eg audio, video, telemetry, tactical data link information) to the TENA Common Infrastructure network to enable TENA applications to interoperate with each other; and

   iii. the **Logical Range Data Archive**, this archive contains all the data necessary to run a specific logical range, including the scenario, initialisation information, data collected during an event, and summary information specific to a given logical range. It is the primary means for non-real-time (persistent) communication between applications in a logical range.

d. **The TENA Object Model (yellow)** – the common language used for communication between all range resources and tools. The set of objects used in a logical range is the Logical Range Object Model and may contain TENA standard object definitions as well as non-standard (*ad hoc*) object definitions.

e. **TENA Utilities (blue)** – applications specifically designed to address issues related to usability or management for the new TENA concept of a logical range; part of the “TENA Product Line”. These utilities make it easier for users to manage and interact with the TENA infrastructure throughout the range event lifecycle. These TENA utilities are mainly concerned with creating, managing and manipulating basic data, objects, models etc. contained within the TENA Repository and the Logical Range Data Archive. Example utilities to manage Logical Range Object Model (LROM) object development are an LROM Object Syntax Checker, an LROM Object Definition Code Generator, an LROM Schema Generator, an LROM Verifier Tool, etc. Other utilities include a Repository Manager and Browser, Logical Range Planning utilities, Data archiving, recording and replay utilities and a Gateway Manager utility.

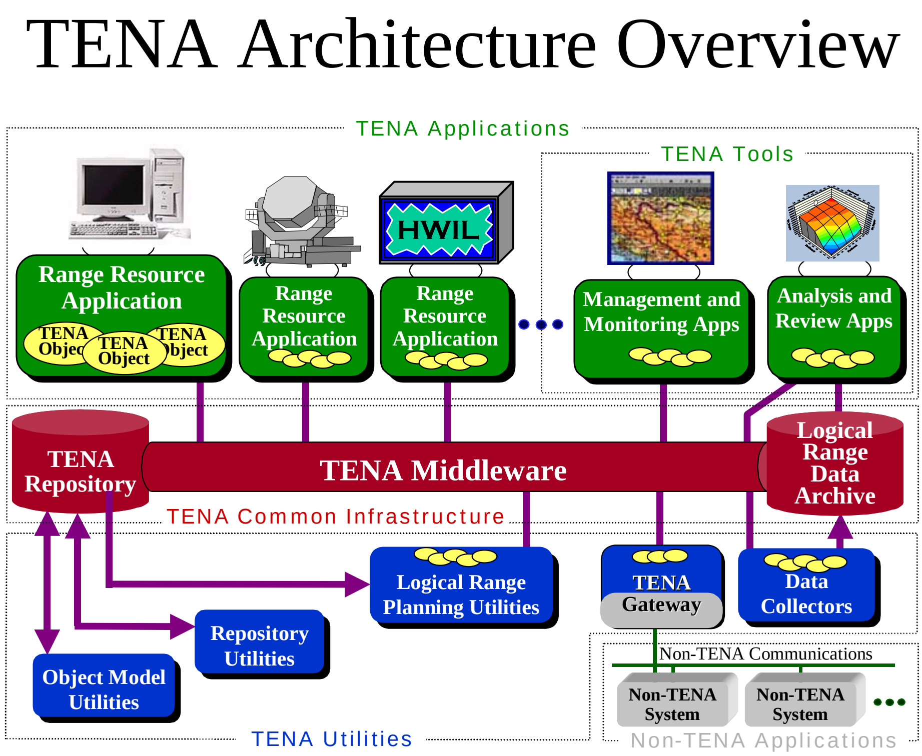


**Figure 2-7: An Overview of TENA**

## 2.4.2 The TENA product line

50. The TENA Product Line addresses the question of what tools, utilities, and gateways need to be built to provide support throughout the entire TENA event lifecycle. Such a Product Line describes a set of applications, with complementary functionality, that share a

core set of components that will allow seamless interoperability. Creating such a Product Line is anticipated to take many years. A number of utilities and tools have been defined to assist the user in creating and managing a logical range as well as dealing with the elements of the TENA common infrastructure. Utilities assist the user in making TENA work as an architecture, while Tools are generally reusable applications that help the user efficiently create and manage logical ranges.

51. There are four basic categories of applications in the Product Line Architecture:

a. **Range Resource Applications –** created by range engineers to perform all of the display, acquisition, processing, control, and environmental representation functions on their range, and specific to each range.

b. **TENA Utilities –** applications created as part of the TENA development process, to facilitate the smooth function and transition of TENA into the range community.

c. **TENA Tools –** reusable TENA applications, that are relevant to many ranges, and have been made available to the range community as a whole.

d. **Gateways –** applications that bridge TENA to other architectures.

52. A view of the TENA Product Line, illustrating the relationships and information flows between the range resource applications and TENA Tools (green), TENA Utilities (blue), the TENA infrastructure (red), and the external, non-TENA applications (gray), using the same colour as used in Figure 2-7, is shown in

53. Figure 2-8. All of these products do not necessarily exist. Some communication between these applications and each other, or with the Logical Range Data Archive, is shown as direct communication for clarity, even though in reality such communication will be via the TENA Middleware.

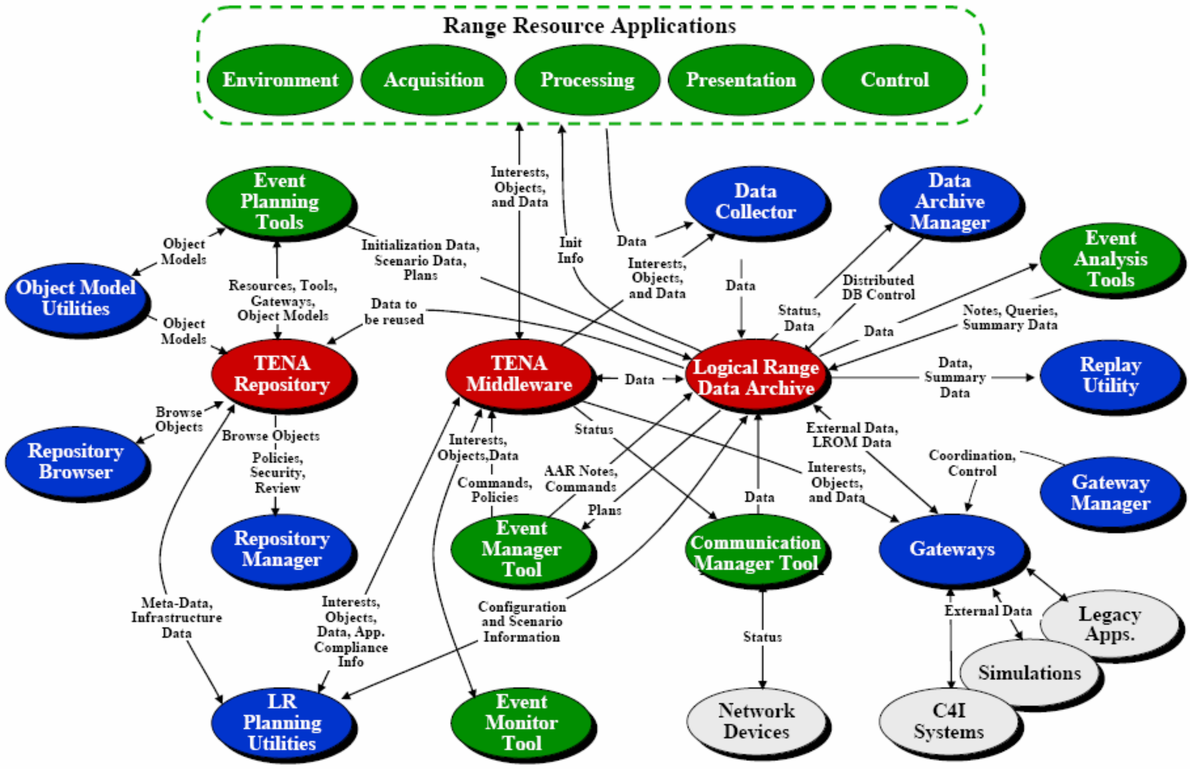


**Figure 2-8: The TENA Product Line**

### 2.4.3 The TENA standardisation process

54. The TENA object model is being developed using a prototype-based, iterative approach. Only object definitions that have been tested at multiple ranges during many logical range executions can be advanced for standardisation. The Logical Range Object Model can contain object definitions that are either custom-designed for that particular logical range or are in the various stages of standardisation. In this way, the range community is not forced to use object definitions that may be inappropriate for their logical range, but TENA still promotes the standardisation that is necessary to create interoperability. After object definitions have been tested and used they can be put forward to the TENA Architecture Management Team (AMT) as candidates for formal standardisation. The AMT is responsible for studying these definitions and de-conflicting them with any other object definitions that have already been put forward for standardisation. When the AMT approves the object definitions, they are advanced to the range community standards body, the Range Commanders Council (RCC), for formal standardisation. When a substantial fraction of the range community information domain is standardised, interoperability between range resource applications will be greatly enhanced.

55. TENA is being migrated onto the ranges gradually, one range resource application at a time. TENA defines such a gradual process based on the judicious use of gateways, providing the range community a mechanism to begin to deploy TENA without disrupting current range operations.

### 2.4.4 Advantage and disadvantages of TENA

56. The advantages of using TENA are as follows:

a. TENA is a US Department of Defence Project specific “standard”. TENA is managed by US DoD Foundation Initiative 2010 Project.

b. TENA is specific only to the real-time, Test and Training Range domain.

c. TENA provides support for the entire TENA event lifecycle.

d. TENA interoperability is required and is currently provided through the single source TENA Middleware. It is intended that the Government-Off-The-Shelf (GOTS) TENA Middleware product be made “Open Source”.

e. The TENA Product Line specifies tools, utilities, and gateways that support the entire TENA event lifecycle and interoperate seamlessly.

f. A TENA Operational Architecture that provides a concept of operations for planning, creating, testing, and using a logical range is part of the overall TENA Architecture.

g. An incremental TENA compliance strategy is part of the TENA Architecture.

h. TENA will have gateways for DIS and HLA to aid interoperability with these existing, widely used, distributed simulation standards.

57. TENA has the following disadvantages:

a. TENA is specific only to the real-time, Test and Training Range domain. Therefore, it has limited ability to support application areas such as experimentation, force assessment, crisis management and planning, and Research and Development. Some training (eg strategic and operational) and testing applications where a non-real-time is required are also limited.

b. TENA is a developing architecture – it is not a mature technology.

c. Not much information is available on TENA.

d. TENA is not yet released to Australia.

e. TENA is not yet an IEEE open standard.

# 3 GUIDANCE FOR COMBINING SIMULATIONS

58. The Defence Organisation envisages increased integration of Simulation into Defence processes, at both a micro and macro level. Since the macro level processes typically cross the boundaries between elements of the Defence Organisation, this expanded use of Simulation is likely to require the combination of many discrete Simulations. The process of combination will require, in the main, physical interconnection of Simulations via computer networks and ensuring Interoperability of the information flowing across these networks. Connection to the Simulations of coalition partners is also envisaged.

59. This concept is represented in Figure 3-1. Many Simulations are developed to represent individual systems. The Simulations can either be physically connected to fully represent physically connected systems or pass data via some other means. The Simulations themselves can be physically or non-physically connected to real systems to provide a higher level of Fidelity not able to be easily represented in the real world. It is important that the individual simulations remain concurrent with the real systems they are representing.

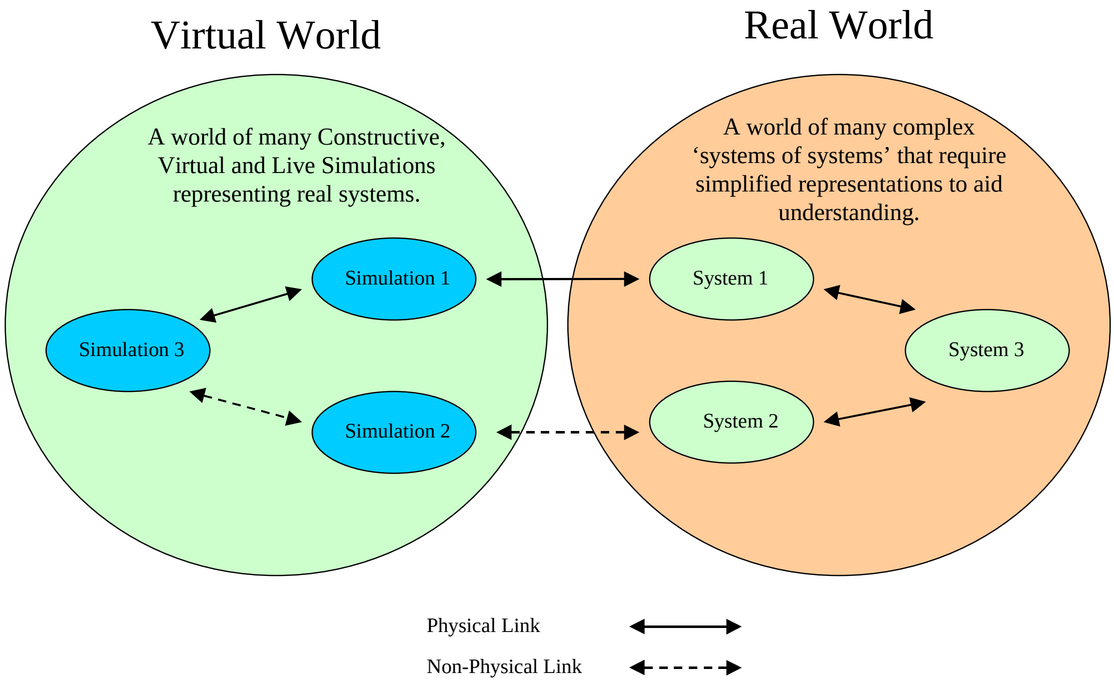


**Figure 3-1: The combination of simulations can better meet real world needs**

60. The early efforts at combining Simulation have focused on Real-Time training simulators, for which both DIS and HLA are suitable. Current thinking on the longer-term vision for Simulation in Defence indicates the combining of Simulations in other than real time is likely to be required. Of the two options, only HLA supports such a requirement.[11] Also, Australia's allies, particularly the US, are adopting HLA. Some degree of HLA compatibility will be required in order to participate in the preliminary – and probably mandatory – Simulation sessions which are likely to precede major coalition exercises. Consequently, the Defence Organisation needs to plan to adopt HLA, even though DIS is, and is likely to remain, appropriate for some situations.

xi. [11] The DIS standard indicates some non-real time capability, however, this is not used in practice (see Section 6.1.1.12).

## 3.1 ADDRESSING THE SIX SIMULATION CRITERIA

61. The Defence Simulation Policy requires that each proposal to develop and/or combine Simulations needs to be informed by an assessment made against the following criteria:

a. **User requirements**—who wants the Simulation?—why?—to do what exactly? In particular, what questions are to be answered with the help of Simulation?—or what training needs are to be met?

b. **Representations**—how are people and things with their dynamic behaviours and interactions in various environments going to be represented inside the Simulation?

c. **Data availability and reliability**—how well can these representations be activated?—does the necessary data exist?—can the appropriate data be found?

d. **Technology**—how can the ideas embodied in the answers to subparagraphs a., b., and c. of this paragraph be made to work effectively for the User via appropriate technologies?

e. **Confidence building approaches**—how is ‘fitness for purpose’ to be assessed to establish both the overall credibility of Simulation outcomes and the necessary levels of User confidence in them?

f. **Cost/benefit**—how are the returns on investment to be determined and expressed in order to secure both the initial and the continuing resources needed to build, deploy and use the system?

62. These criteria prove to be the key to forming the necessary professional judgements about the long-term viability and success of a Simulation project. Consequently, all proposals for future Simulation projects within the Defence Organisation are to be framed in accordance with these criteria.

63. The Simulation Proposal Guide (SPG) was designed to assist the Developers of Simulation proposals, and those reviewing and assessing those proposals, to establish clearly how the Simulation will enhance capability, save resources or reduce risk to develop, train for, prepare for and test military options for Government. The conceptual framework is illustrated in Figure 3-2. The SPG is available online via the ADSO website.

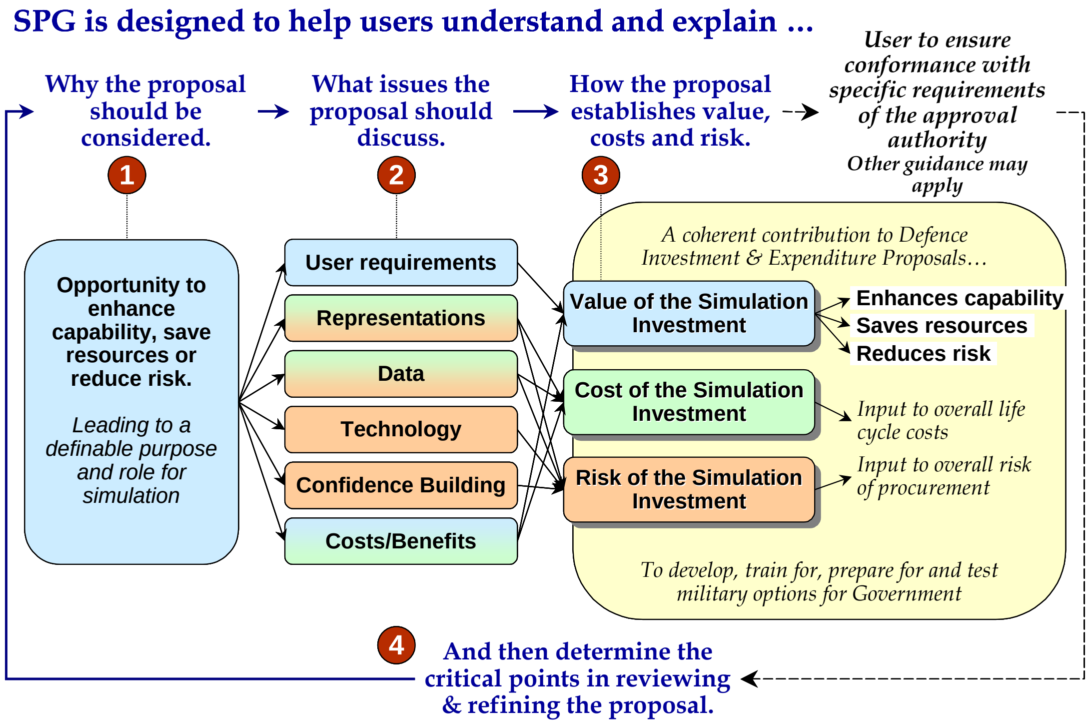


**Figure 3-2: Concept for Simulation Proposal Guide**

## 3.2 DESCRIBING THE INTERFACE

64. It is essential that Simulations that have been combined or are intended to be combined have interface documents that are accurate and fully populated to define the external interface. This also applies to Simulations that are interfaced to real systems. This will ensure that risk is reduced and resources saved when combining these Simulations with other systems.

ADSO recommends that all Simulations that are to interface to other simulations or real systems use the documentation process as defined in MIL-STD-498, 'Software Development and Documentation'. Particular attention should be paid to the Interface Requirements Specification (IRS) and Interface Design Description (IDD) Data Item Descriptions (DID).

65. The standard and DIDs are available from http://www.pogner.demon.co.uk/mil_498/.

## 3.3 SAFETY CONSIDERATIONS

66. Simulation by itself is not a safety hazard and can be used to mitigate safety risks. However, when Simulation is used to interoperate or interconnect with real systems (people, equipment and processes), there is an increased degree of safety risk that could be imposed by the Simulation. This safety risk will need to be identified and reduced to an acceptable level (where necessary), and any remaining residual risk pro-actively managed in accordance with current safety policy. In some high-risk applications (eg embedded Simulations) a safety case will need to be documented and submitted to the relevant approval authority.

67. The safety risk that Simulation can impose on the real world can be considered direct and indirect:

a. Direct

i. The Simulation directs a weapon to behave unexpectedly.

ii. The Simulation directs a radar or laser to behave unexpectedly.

iii. The Simulation directs other equipment to behave unexpectedly.

iv. The Simulation imposes adverse psychological effects on personnel.

b. Indirect

i. The Simulation causes simulated data to be stored in the real system and this data inadvertently causes the real system equipment to behave unexpectedly when operated.

68. Safety will also need to be closely analysed and managed when 'live' and 'virtual' operations are being conducted at the same time. Further Guidance can be found in the Simulation Safety Guide.

## 3.4 COMMERCIAL SOFTWARE

69. In many situations, Simulations are combined using middleware provided by the commercial sector. There are a number of risks with using commercial software to combine Simulations that Developers and Managers need to consider. These are:

a. Typically commercial vendors release only binary versions and are reluctant to release the source code. Therefore, a buyer depends heavily on the binary distribution providing the necessary functionality and/or availability of sufficient support documentation and upgrades[12].

b. Commercial vendors tend not to allow their software packages to be compatible with software tools from other vendors. This means that vendor lock-in is a long-term issue.

c. Commercial software can be substantially more expensive than in house options. However, this additional cost needs to be assessed against the long-term support benefits that may be available from a commercial vendor.

d. The level of verification, validation and accreditation of commercial software can not be readily accessed.

### 3.4.1 High level architecture-specific issues

70. Many COTS products are distributed as two binaries: one for DIS and the other for HLA. Other software may be written exclusively for HLA or exclusively for DIS. The latter can inter-operate with a HLA Simulation via a DIS/HLA gateway (see Section 3.6), provided that certain conditions are met. Since the source code is generally not available compatibility and suitability must be carefully considered. The following compatibility issues are specific to HLA products [13]:

xii. [12] Source: Reference T.
xiii. [13] Source: Reference T.

a. Is the software supported under the required version of the RTI? Ideally it would have been tested against the RTI of the exact same version, as used in the intended environment.

b. Does the software use a compatible FOM? If not, is it FOM agile?

c. How mature is the HLA version of the software? Just because a program is known to be mature and runs well under DIS, carries no guarantees for HLA.

## 3.5 COMBINING DISTRIBUTED INTERACTIVE SIMULATIONS

### 3.5.1 Distributed interactive simulation interoperability

71. The reader should be aware that two DIS implementations may not be similar and may use different DIS versions, PDUs and enumeration sets. For this reason it is recommended that a thorough examination of the Simulation interface documentation is conducted at a very early stage to determine DIS Interoperability issues. Further detail on DIS Interoperability issues are discussed below.

#### 3.5.1.1 Different distributed interactive simulation versions

72. To combine two DIS Simulations, the two Simulations must recognise the same DIS version PDUs. Each PDU has its own enumeration field for the ‘version’ of DIS used. Additionally, each DIS version consists of a different PDU set (see Section 6.1.1). Some DIS Simulations of the same version may also use experimental PDUs that could lead to incompatibility.

*Note 8. It is recommended that the IEEE 1278.1a-1998 Standard PDUs be utilised for DIS Interoperability.*

#### 3.5.1.2 Protocol data unit interoperability

73. Although, the PDUs used in two separate Simulations may have the same name this does not imply that the PDUs are compatible. The PDUs may not be fully populated or the enumeration sets defined by each PDU may differ (see Section 6.1.2).

*Note 9. IEEE 1278.1a-1998 lacks definition regarding the implementation of some PDUs; and, while the implementation of DIS in different simulators may be compliant, linking these simulators may sometimes result in unexpected behaviours.*

#### 3.5.1.3 Exercise management

74. DIS exercises identify sites by a number in the range: 0 – 65535. Australian simulators are required to use site Ids with 13xxx numbers (based on 13=Australia in DIS). The 13xxx number space is divided as shown in Table 3-1:

**Table 3-1: Recommended Australian DIS Site Ids**

| | |
|---|---|
| Navy: | 13000 to 13199 |
| RAAF: | 13200 to 13399 |
| Army: | 13400 to 13599 |
| Joint: | 13600 to 13699 |
| DSTO: | 13700 to 13799 |
| Other: | 13800 to 13999 |

### 3.5.2 Supporting tools

75. See Supporting Tools of Guidelines for Building a DIS Simulation (Section 6.2).

## 3.6 COMBINING DISTRIBUTED INTERACTIVE SIMULATIONS TO HIGH LEVEL ARCHITECTURE SIMULATIONS

76. Migration of DIS to HLA is available via[14]:

a. a gateway;

b. middleware; or

c. native HLA integration.

77. **Gateway approach**: A DIS/HLA gateway converts between DIS PDUs and HLA services in both directions in 'Real-Time' whilst the Simulation exercise is running. The gateway is the simplest approach to implement HLA Compliance, as the only modification required is to place the gateway on the network. (this is usually implemented on another computer which sits on the network). However, this approach is likely to result in the highest Latency. Where the benefits of HLA (interaction with Constructive Simulations, reduced broadcasting of data, etc) are not required, the gateway remains the most effective approach to retain the benefits of Interoperability provided by DIS, whilst still having the ability to connect via HLA.

78. **Middleware approach**: To implement the middleware approach, the application uses a higher level (abstraction) interface that can be used for both DIS and HLA services. Since the topmost HLA software layer works in parallel with, or replaces, the equivalent DIS software layer, Latency is reduced compared to the gateway approach. This allows software investment to be maintained. Note that changes to the simulator code may be required, and in a proprietary environment could be very expensive.

79. **Native Integration**: A native integration is a tight coupling between HLA and simulator code. The DIS paradigm is replaced by the object oriented philosophy of HLA. This approach should provide all the benefits of HLA but at a substantially higher initial and continuing cost. Since the interface code is FOM dependent, considerable software development and associated maintenance will be required, and backward DIS compatibility is unlikely unless a FOM similar to the RPR FOM is used.

### 3.6.1 Real-time platform reference federation object model

80. Various reference FOMs such as the RPR FOM have been proposed to assist with conversion of DIS-compatible systems to HLA and to further promote Interoperability.

81. The RPR FOM was proposed as a reference FOM for Real-Time platform level Federations to facilitate the transition for DIS compatible Simulations to HLA. It is thus a HLA description of the DIS Protocols.

xiv. [14] For more detailed information relating to DIS to HLA migration, the reader is referred to Reference S.

82. Federation designers can use the RPR FOM as a reference FOM to further develop their own FOMs for their own applications. However, by doing this they are limiting Interoperability with other standard RPR FOM simulators and therefore making the reference FOM less useful.

83. A guidance document accompanies the RPR FOM and is entitled 'Guidance, Rationale, and Interoperability Modalities for the Real-time Platform Reference' or simply known as the 'GRIM' (see Reference L) It provides the usage rules for the RPR FOM, and the definitions, descriptions and rationale not otherwise specified within the standard FOM format.

#### 3.6.1.1 Real-time platform reference federation object model version 1.0

84. RPR FOM 1.0 supports DIS IEEE-1278.1-1995 DIS functionality and is now a SISO standard. Development was commenced in 1997 and the RPR FOM 1.0 was released as a SISO standard in 1999.

#### 3.6.1.2 Real-time platform reference federation object model version 2.0

85. RPR FOM 2.0 added support for DIS IEEE 1278.1a-1998 functionality including features such as environmental representation and underwater warfare.

86. The RPR FOM is provided in both DoD HLA V1.3 and IEEE 1516 compatible data formats.

ADSO recommends using RPR FOM 2 as the baseline FOM for future applications that involve DIS to HLA Interoperability.

### 3.6.2 Supporting tools

#### 3.6.2.1 Commercial products

87. All mainstream COTS HLA RTI vendors provide DIS/HLA Gateway products that are compatible with their HLA RTIs. See Annex E.

#### 3.6.2.2 DSTOs distributed simulation infrastructure library interposer

88. It is intended that the DSILI package (explained further at Section 3.7.2.3) will receive an upgrade to interface directly with DIS Simulations. This will involve the use of DIS packet generators and DIS to RPR FOM gateways.

## 3.7 COMBINING HIGH LEVEL ARCHITECTURE SIMULATIONS

*Note 10. Today we are currently modifying simulators (as discussed in Section 3.6) to be able to participate in a HLA Federation (or FOM). However, in the future, Federates will need to be able to participate in multiple Federations (ie single service, national and coalition FOMS). Federates will need to be able to rapidly transition from one Federation to another in minimal time and minimal impact.*

89. The options identified for linking new and pre-existing Simulations and Federations into Federation communities are:

a. off-the-shelf gateways,

b. use of SIMplicity to modify HLA interfaces to Federates for which there is access to source code or a well-defined API, and

c. application of DSTO DSILI to construct custom run-time gateways.

90. **Off-The Shelf Gateways**: The evidence to date is that the off-the-shelf gateways are almost universally geared towards support for RPR FOM version 1. Coupled with the observation that very few applications utilise this version of the RPR FOM without change, a measure of customisation is required and tools are emerging that provide for this.

91. **SIMplicity**: SIMplicity provides for the rapid construction of HLA interfaces and, if there is access to the Simulation source code, or the Simulation presents a well defined API, is a means for constructing custom interfaces on an as-needs basis (see Section 7.2.1.1).

92. **DSTO DSILI**: The DSILI technology (yet to be demonstrated) has the potential to provide a technological solution to the FOM Agility problem, particularly in cases where the Commonwealth does not have access to the Simulation source code, such as third party software tools. In addition to the significant advantage this offers in terms of permitting re-use of unsupported Simulations, an implication that flows from recognition of the DSILI capabilities is that products from multiple vendors may be more readily used, thereby reducing the prospect that Defence is exposed to vendor lock-in (see Section 3.6.2.2).

## 3.7.1 The proposed Australian Defence base object model/s

### 3.7.1.1 Why have a common Australian Defence base object model framework?

93. Simulation is increasingly being used to support many Defence Organisation processes, ranging from experimentation and concept exploration, to acquisition and through-life support. In achieving this end a critical requirement is to integrate Simulations both to increase the richness of simulated scenarios and to reduce cost through re-use. ADSO acknowledges that DIS has been applied to link RAN training simulators but HLA provides the breadth of functionality to fulfil the vision of widespread and integrated use of Simulation in support of key defence processes.

94. The Australian Defence Base Object Model (ADBOM) framework will not only promote Simulation reuse, but encourage the agile, rapid and efficient development and maintenance of interoperable Simulation environments. The common ADBOM framework will improve Simulation Interoperability by:

a. defining a common foundation for Defence Simulation FOMs. This will amount to a common set of semantics, entity interactions and conceptual representations. It is acknowledged that User groups have specific requirements that will fall outside the common elements encompassed by the ADBOM. framework These specific elements will, however, need to be managed by the User group.

b. defining and supporting a common RTI set for Australian Defence Organisation use.

c. allowing a degree of re-use.

d. allowing a common Australian toolset to be developed. Tools such as SIMplicity will encourage Simulation Developers to engineer their Simulations in such a way that the effort in conforming to the ADBOM framework is minimised.

e. allowing a standard documentation set to be developed.

f. allowing a degree of compliance and configuration management of Australian Simulations.

95. The ADBOM framework will support DIS by being interoperable with the current and future RPR FOM standards. The ADBOM framework will also maintain Interoperability with Allied and Coalition FOMs.

96. Figure 3-3 shows the current view of how the proposed common ADBOM framework may look. The ADBOM framework will be a component of the common foundation of the Joint Simulation Capability (refer to Section 10.4.1).

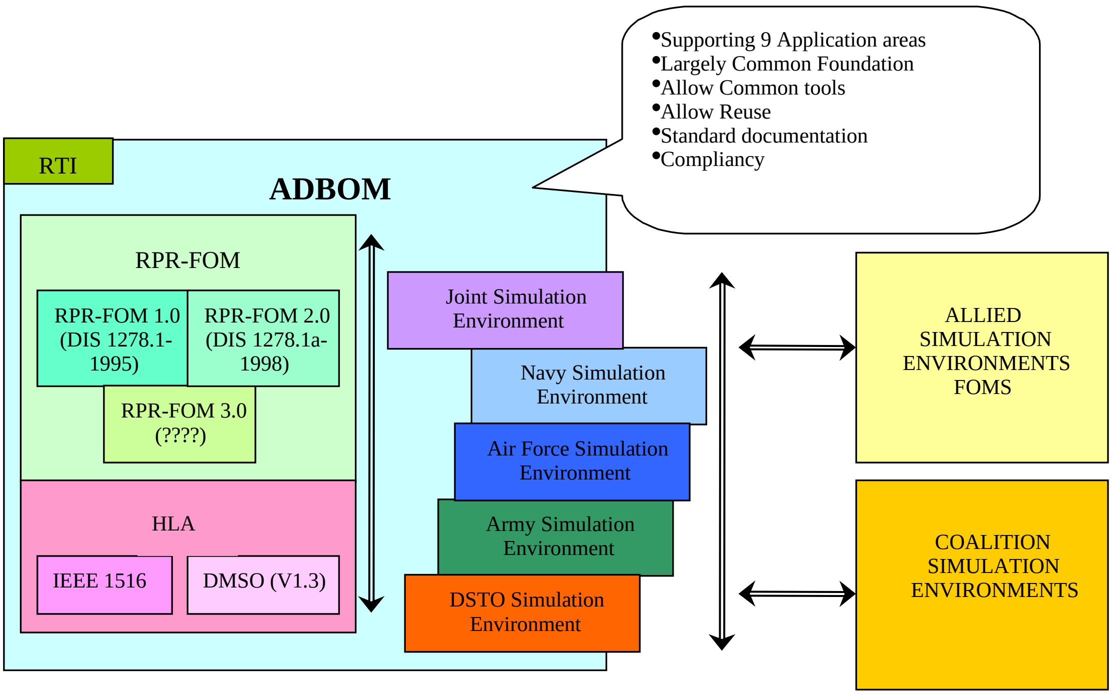


**Figure 3-3: Current View of the Common ADBOM Framework**

#### 3.7.1.2 Australian Defence base object model guidelines

97. A study will be conducted by ADSO and DSTO to develop the guidelines for the common ADBOM framework, which will aid in its development. The study will investigate current international BOMs for applicability to the Australian environment. In the meantime technologies such as SIMplicity and DSILI provide some means for Simulation Interoperability to be achieved whilst the common ADBOM framework is developed. Again, these tools may allow extant Distributed Simulations to be integrated to the common ADBOM framework, without change to the extant Simulations.

### 3.7.2 Supporting tools

#### 3.7.2.1 Commercial tools

98. Refer to Section 3.6.2.1.

#### 3.7.2.2 SIMplicity

99. SIMplicity provides a partial solution to the FOM Agility problem in the event that there is a well-defined Application Programmer Interface. For more information on SIMplicity, refer to Section 7.2.1.

#### 3.7.2.3 DSTO distributed simulation infrastructure library interposer

100. Through research led by MPD (DSTO), and supported by the University of Ballarat under a contract funded by ADSO, a technology is being developed that will provide for FOM Agility without the need for access to the underlying Simulation source code. The DSILI intercepts calls made by a Simulation on the RTI and by the RTI on a Simulation, before passing them on. This ability to intercept messages provides an opportunity to transform them both before they are passed to the rest of the Federation and before inbound messages are passed to the Simulation. These transformations may be constructed in such a way that they map one FOM to another. The DSILI therefore provides a potential technological solution to the FOM Agility problem in a manner that does not require access to Simulation source code. The DSILI concept is not limited to HLA. It can be readily extended to support other Simulation Protocols, such as DIS or whatever the next generation of Distributed Simulation Protocols may be. It may also be extended to support other distributed computing infrastructures, such as .NET. The DSILI has the potential to provide for a security layer in Distributed Simulation.

# 4 INTEROPERABILITY CONSIDERATIONS

## 4.1 INTEROPERABILITY VS INTERCONNECTIVITY

101. Interoperability and Interconnectivity can be defined as:

a. *Interoperability*: the ability of systems, units or forces to provide services to and accept services from other systems, units or forces and to use the services so exchanged to enable them to operate effectively together.[15]

b. *Interconnectivity*: the linking together of interoperable systems.[16]

Interoperability is about correct behaviour, and when applied to a Simulation is concerned with the level of Fidelity that fully represents the real world being simulated, and the interfaces among Simulations and systems. Interconnectivity is concerned with the connection via an information technology link such as landline or an RF link. A Developer would generally be concerned with Latency, Necessary Bandwidth and Architecture issues. Interconnectivity is further explored at Section 5.

102. When we talk about Interoperability between Simulations we must not confine our thinking to those Simulations that are interconnected. We must also consider stand-alone Simulations where some form of Interoperability is still required. For instance, stand-alone Simulations may require data input from another source to obtain a desired level of Fidelity; or may need to interoperate with real systems for testing purposes, which means that concurrency between the Simulation and the real world system may be vital.

103. The degree of Interoperability that is required needs to be analysed to meet the desired performance objectives. A high level of Interoperability may not be necessary for success in terms of operational performance or may not be affordable or technically feasible. Higher levels of Interoperability require ongoing coordination between independent programs, increased levels of engineering development, and robust configuration management. [17] However, low levels of Interoperability require increased manual intervention. The Developer or Manager should assess the degree of Interoperability required.

## 4.2 SIMULATION INTEROPERABILITY BETWEEN DEFENCE PROGRAMS

### 4.2.1 Defence information environment approved technology standards list

104. The Defence Information Environment[18] Approved Technology Standards List (DIE ATSL), contains the mandatory technology standards that must be used (as appropriate) for all DIE Information Infrastructure (DII) and Communications and Information Systems (CIS) and Management Information Systems (MIS) to improve local Interoperability.[19] It is

xv. [15] ADFP 1, 30 Nov 93.
xvi. [16] US Joint Pub 1-02 (as amended to 1 Sep 2000).
xvii. [17] Source: Reference V.
xviii. [18] The Defence Information Environment is a single entity that encompasses intelligence, surveillance, reconnaissance, communications, information warfare, electronic warfare, command and headquarters systems and management (logistics and business) systems.
xix. [19] Refer to DIMPI 3/2002 - Defence Information Environment – Approved Technology Standards List.

intended to be used by all Australian Defence Organisation staff that are responsible for DIE-related capability development, Architecture development, procurement and projects, including Defence consultants and contractors. The DIE ATSL is also used to inform Industry, other Government departments and allied organisations of the Australian Defence Organisation position on information and communications technology standards and related DIE Architecture technical views.

105. Currently, no Simulation standards have been incorporated into the DIE ATSL. Moves are currently underway to include the following standards:

a. IEEE 1278.1a (1998) for DIS;

b. IEEE 1516 (2000) for HLA;

c. Synthetic Environment Data Representation and Interchange Specification (SEDRIS)[20]; and

d. STANAG 5602 – Standard Interface for Multiple Platform Link Evaluation (SIMPLE) for Link 11 and 16 Simulation.

## 4.3 SIMULATION INTEROPERABILITY WITH COALITION PARTNERS

### 4.3.1 Allied data publication 34, volume 4 – NC3 common standards profile

106. During the late 1990's, the Combined Communications Electronics Board (CCEB) and NATO separately developed technical architecture standards to help promote C4/CIS Interoperability between their member nations. This was duplicative effort for US, UK and CA, and consequently CCEB and NATO agreed to harmonise the two technical architectures to improve 'global' Interoperability. In June 2002, the CCEB Principals endorsed AdatP-34 Volume 4 as the agreed technical architecture between AS, CA, NZ, UK and US. AdatP-34 Volume 4 is the NC3 Common Standards Protocol (NCSP) and lists agreed standards over a wide range of functional areas. Only Volume 4 of the NC3TA is relevant to Australia and the CCEB, as Volumes 1-3 and 5 are NATO-specific.

107. On 13 November 2002, the Chief Information Officer issued DIMPI 2/2002 – Combined Interoperability Technical Architecture Standards – which issues policy requiring those involved in the acquisition of DIE technologies to ensure that the technical architecture/views comply with the Defence Architecture Framework and AdatP-34 Volume 4. The DIMPI requires adherence to applicable technology standards as detailed in the latest version of AdatP-34 Volume 4. These standards are mandated for all future Defence contracts when there is a known or potential requirement to operate with CIS of CA, NZ, UK or US.

108. Standards listed in AdatP-34, Volume 4 (Version 4) that relate to Distributed Simulation are:

a. STANAG 4482 for DIS;

109. Moves are currently underway to include the following standards:

xx. [20] For further information on SEDRIS the reader is referred to: http://www.sedris.org.

a. STANAG 4603 for HLA;

b. SEDRIS; and

c. STANAG 5602 (SIMPLE) for Link 11 and 16 Simulation.

### 4.3.2 US Naval training meta federation object model

110. The Naval Training Meta FOM (NTMF)[21] is being developed to achieve meaningful Interoperability with US Navy and Marine Corps legacy and new training systems under HLA. The NTMF combines elements of SISO's RPR FOM 2.0, the US Navy's BFTT FOM (used in the BFTT Operator Processing Console), the US Defence Information Infrastructure Common Operating Environment and the US Tactical Environment Data Server.

## 4.4 SIMULATION/C4ISR SYSTEM INTEROPERABILITY

111. Many efforts[22] are ongoing within the international community to address Simulation to Command, Control, Communications, Computer, Intelligence, Surveillance, and Reconnaissance (C4ISR) system Interoperability. However, these efforts have largely been uncoordinated. In an attempt to coordinate these efforts SISO established the C4I Study Group to investigate the current activities and recommend a way forward. The SISO C4I Study Group called for,

> a standard frame of reference, in the form of a Command, Control, Communications, Computer, Intelligence, Surveillance, and Reconnaissance (C4ISR)/Sim Technical reference Model (TRM), for Interoperability between C4ISR and Modelling and Simulation systems, which would define methods and levels of Interoperability of systems or classes of systems.[23]

112. Simulation interfaces to C4ISR systems in the ADF will be essential to support: training, experimentation, acquisition, life-cycle management, crisis management and planning, mission rehearsal and conduct of operations. In Australia, the Simulation community has standardised on certain Protocols (such as HLA and DIS) and the C4ISR community is currently exploring a common Architecture that may be similar to the US Joint Technical Architecture. Some programs are clearly moving towards developing interfaces between C4ISR and Simulation systems.

xxi. [21] The NTMF working group website can be found at: http://www.ntmf.com/.

xxii. [22] The SISO C4I Study Group produced a report entitled, 'Report Out of the C4I Study Group' that contains a good history of C4ISR to Simulation interfacing for NATO nations and the US.

xxiii. [23] Source: Reference V.

### 4.4.1 The C4ISR/Simulation technical reference model

113. The SISO goal of the TRM is to assist programs to achieve more effective levels of portability and Interoperability by:[24]

a. providing consistent and common lexicons for description of Interoperability requirements between diverse systems,

b. providing a means for consistent specification and comparison of system/service Architecture,

c. providing support for commonality across systems,

d. promoting the consistent use of standards, and

e. aiding in the comprehensive identification of information exchange and interface requirements.

114. The TRM focuses on the generalised interfaces that establish Interoperability between C4ISR systems and Simulations. SISO has put forward the TRM Functional Interface Graphic (FIG) (Figure 4-1) for broadly categorising these interfaces. The four main groups of interfaces are defined as follows: [27]

a. **Simulation Service Interactions** are exchanges of information that primarily support the Simulation systems requirements;

b. **Non-Persistent Data** is data that will likely change during the course of an event (ie the interface must support dynamic updates);

c. **Persistent Data** is data that is reasonably static and generally set during system initialisation (note: this data could possibly reside in a common C4ISR/Sim database); and

d. **C4ISR System Service Interactions** are exchanges of information that may be mandated by use of particular C4ISR components, or merely by virtue of being connected to a C4ISR system.

115. In order to achieve effective Interoperability, all of the represented data interfaces need to be considered by the interface Developer. The TRM FIG data definitions, examples and commentary can be found in the C4ISR/Sim Technical Reference Model Sourcebook at http://www.sisostds.org/.

ADSO recommends that Developers adopt the TRM FIG terminology when developing interfaces between C4ISR and Simulation systems.

xxiv. [24] Source: Reference V.

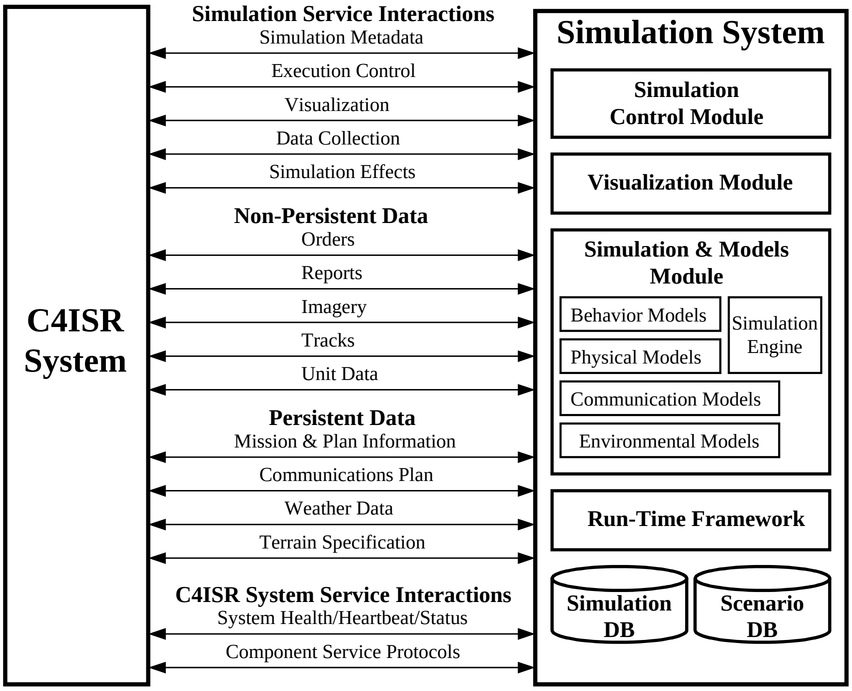


**Figure 4-1: TRM Functional Interface Graphic**

### 4.4.2 Voice Communications Interoperability

116. An important component of Distributed Simulation, for training purposes in particular, is the ability to simulate voice communications between entities. DIS includes PDUs to convey radio and intercom information, and, as well as permitting voice communications between participants, provides for special effects, such as line of sight limitations, meteorological interference, encryption and jamming.

117. When planning the communications infrastructure, it is important to consider the number of circuits that may be required. This may include those circuits that are used in the real-world environment, plus additional circuits for internal and external game and network management.

118. COTS products that provide DIS voice communications capability exist, and at least one Australian simulator manufacturer has developed a DIS compatible voice communications system. To avoid interoperability problems, as well as satisfying the DIS standards, any DIS voice communication system should implement the same radio signal encoding type(s) and other parameters used by other simulations in the network. It should be noted that BFTT uses a proprietary DIS voice system which uses some non-standard parameters, and care is required when interfacing with such equipment. DSTO (AOD) can provide assistance with establishing the appropriate parameters.

119. HLA voice hardware and software products, which support the RPR-FOM 1.0, are also commercially available. However, as with other HLA products, effective HLA voice communication relies on the use of a common FOM and RTI or some form of gateway/agile FOM capability.

### 4.4.3 Tactical Data Link Simulation

120. DIS has provision for tactical data link, eg Link 11 or Link 16, by means of its radio communication PDUs; however, this is not the preferred method, and the standard for

this provision has not matured sufficiently to be widely adopted by the simulation community. Also, there are a number of existing and planned simulations that include real combat system components and have a live Link capability, eg RAN ships with on-board training systems, and the necessity to be compatible with these has been recognised.

121. STANAG 5602 - Standard Interface for Multiple Link Evaluation (SIMPLE) is a NATO standard that enables tactical data link messages to be formatted as digital packets that emulate the physical radio messages used in a live tactical data link network. This method is being employed to achieve Link interoperability between the FFG Upgrade and Maritime Warfare Training Centre projects, as well as with overseas simulations.

122. Even in the real world environment, Link interoperability presents problems, and certification by the ADF TADIL (Tactical Digital Information Link) Authority is required for any system that may interface with other Link systems.

123. COTS Link simulation products exist that have verified Link performance, and it is possible to integrate these with legacy systems that have only an emulated tactical data link capability. The Maritime Warfare Training Centre Project Office can provide further information if requested.

# 5 INTERCONNECTIVITY

## 5.1 INTERCONNECTIVITY ISSUES TO CONSIDER

### 5.1.1 Necessary bandwidth

124. Developers of Distributed Simulations need to consider their Necessary Bandwidth requirements very closely. Not only is the purchase of Necessary Bandwidth costly, but limited bandwidth may result in unacceptably high Latencies at times of maximum activity. The use of HLA will potentially offer a considerable reduction in the maximum bandwidth required.[25]

125. Before conducting distributed exercises, it is recommended that Developers calculate the Necessary Bandwidth. This estimate can then be used to determine the most cost effective bandwidth solution. DSTO can provide assistance with calculating the Necessary Bandwidth.

### 5.1.2 Latency

126. DSTO has developed a methodology to estimate Integrated Services Digital Network (ISDN) Latency.[26] DSTO has determined that ISDN Latencies for DIS WAN Simulations between Australia and New Zealand are within the 100 ms limit for tightly coupled exercises (the limit is 300 ms for loosely coupled exercises) as defined by the IEEE DIS standard. However, for connections to the US, the Latency may exceed 100 ms. Connections to the UK will exceed this limit (see Figure 5-1).

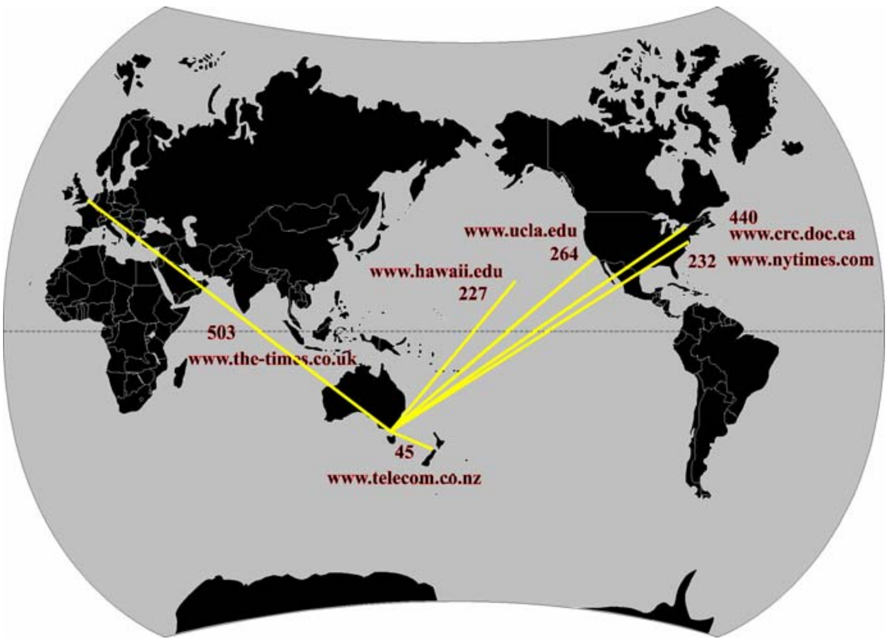


**Figure 5-1: Measured minimum round trip Internet Latencies (in msec) from Melbourne**

xxv. [25] For information on calculating the required bandwidth of a DIS Simulation the reader is referred to Reference Y.

xxvi. [26] Source: Reference X.

127. The following ISDN round trip Latencies from Sydney were predicted by DSTO:

**Table 5-1: Latencies from Sydney**

| City | Latency (ms) |
|---|---|
| Brisbane | 13 |
| Cairns | 24 |
| Darwin | 38 |
| Perth | 36 |
| Adelaide | 18 |
| Melbourne | 14 |

128. There is little difference between the Latency of DIS and HLA: the smaller HLA packet size will only account for negligible reduction in Latency for ISDN lines.

### 5.1.3 Security

129. Three components of a Simulation can be a security concern:

a. The Simulations, which are more or less accurate representations of real world systems, in particular with respect to system behaviour; these Simulations can potentially have the same level of classification as the real system they are representing.

b. The data describing the system, which is usually an input to the corresponding Simulation; this data contains valuable and sensitive information about the system, eg the range of detection for a sensor.

c. The design of the Simulation itself which may incorporate company proprietary information.

The Defence Security Manual (http://intranet.defence.gov.au/dsm/) provides guidance on the physical security measures required to protect systems operating at high security levels. Security issues will need to be addressed before the high security level Simulations can be used. When connecting to allied Simulations/systems additional security measures may need to be addressed. Further guidance can be found in the Simulation Security Guide.

## 5.2 EXISTING AND FUTURE AUSTRALIAN NETWORKS

### 5.2.1 Integrated services digital network services

130. ISDN is an international communications standard for transmitting video, audio and data over digital telephone lines between two Users on the network. An ISDN service provides a guaranteed bandwidth between Simulations. ISDN services are available from commercial communications providers such as Telstra. In Australia, and most other countries, ISDN scales in increments of 64 kbps. A 64 kbps bi-directional bearer channel is called a B-channel. Increasing the bandwidth of an ISDN network requires the addition of more B channels, which can be accomplished automatically with the use of a Router. DSTO recommends that the same Routers or at least Routers from the same manufacturer, at each node of a Simulation exercise be used. This is because routers produced by different manufacturers do not always communicate effectively together. Further information on ISDN networks can be found at http://www.isdnzone.com. Telstra ISDN service details can be found at http://www.telstra.com.au/isdn/index.htm.

### 5.2.2 Internet

131. The Internet links many computer nodes worldwide and accesses whatever bandwidth is available. The Simulation must share the available bandwidth with any other traffic using the service at that time (ie there is no guaranteed bandwidth).

### 5.2.3 Australian academic and research network

132. The Australian Academic and Research Network (AARNet) delivers high-capacity, cost-competitive services and by being at the forefront of innovation, maintains a profile as one of the world's leading academic and research network facilities.

133. AARNet is an internetwork of regional networks, one in each State and Territory (see Figure 5-2). The hubs of the regional networks provide IP connectivity to AARNet members and associates in that region. Connection from the hub to customers is by a variety of carrier and privately owned links. Refer to the AARNet website for further information www.aarnet.edu.au .

*Note 11. AARNET was used for the CReaMS exercise, Virtual Coalition Readiness between the RAN and USN in September 2003.*

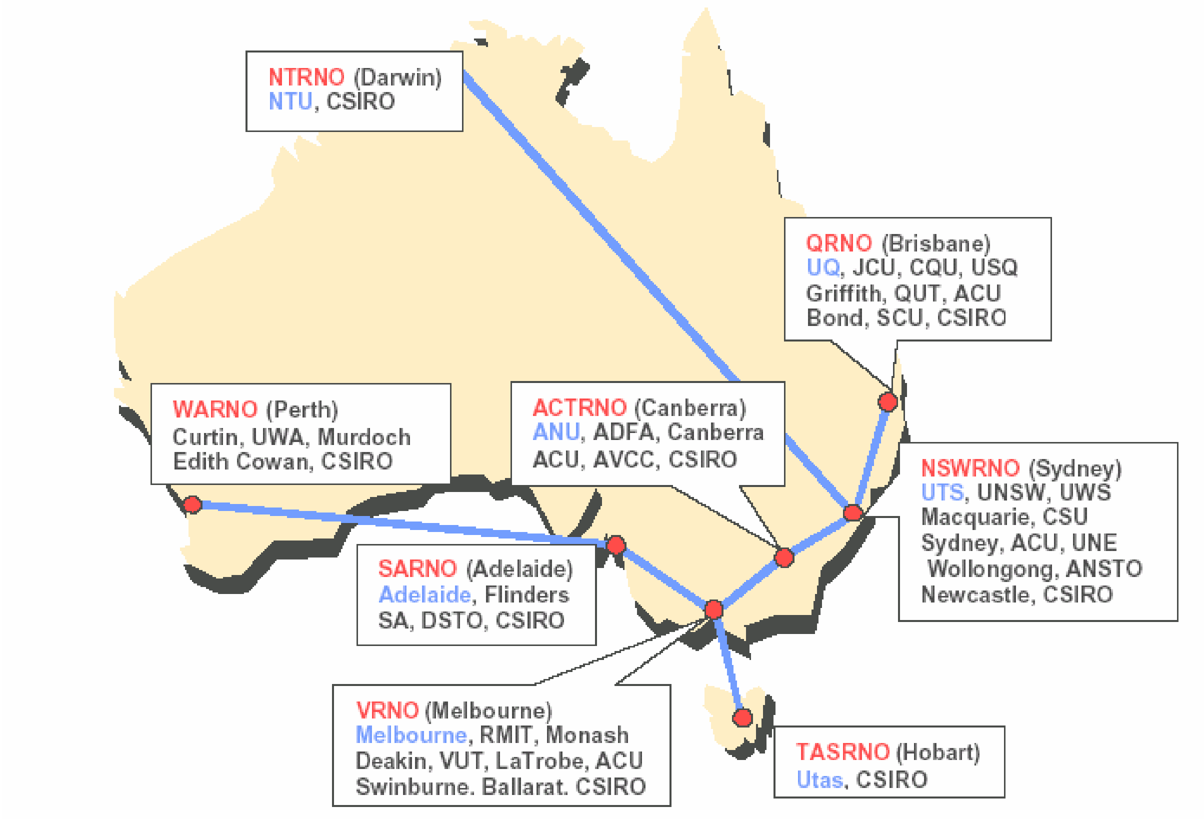


**Figure 5-2: AARNET Australian Backbone Network**

### 5.2.4 JP 2047 – Defence wide area communications network

134. The aim of JP2047 is to establish a Defence Wide Area Communications Network (DWACN) providing seamless connectivity for voice, video, and data communications between fixed elements of Defence. The Defence Wide Area Communications Network will be a secure and scalable network (based on ATM), which will deliver improved availability and capacity. It will allow dynamic sharing of bandwidth, will have the capacity to grow to meet anticipated demands associated with new capabilities and applications, and will yield

cost-efficiencies on future bandwidth needs. In providing the communications infrastructure required to support all Defence establishments across Australia and overseas, DWACN will support the primary Defence mission and will be vital to Defence's command and control.

### 5.2.5 JP 2008 – MILSATCOM

135. JP 2008 is a multi-phased proposal to develop satellite communications capabilities for long distance strategic and tactical communications in support of ADF assets throughout Australia's region of interest. MILSATCOM will support data links of 2.4 kbps using the Cable and Wireless Optus L-Band service. Higher rates may be possible through channel aggregation. Note that a satellite delay of ~ 250 ms per hop (combined uplink and downlink) may cause latency issues.

### 5.2.6 SEA 1442 - maritime communications and information management modernisation project

136. This Architecture will address the external and internal information exchange requirements of surface and sub-surface naval units, naval ship-borne aircraft, Air Force and Army maritime elements, and tactical/operational headquarters including support services.

# 5.3 EXISTING AND FUTURE INTERNATIONAL/COALITION NETWORKS

## 5.3.1 ISDN and internet services

137. Refer to Sections 5.2.1 and 5.2.2.

## 5.3.2 Australian academic and research network

138. The AARNet network provides an incubator for development of advanced network infrastructure and applications with access to the global Research and Education Networks in North and South America, Europe and Asia. Figure 5-3 shows the current and planned AARNet Links. Refer to the AARNet website for further information www.aarnet.edu.au.

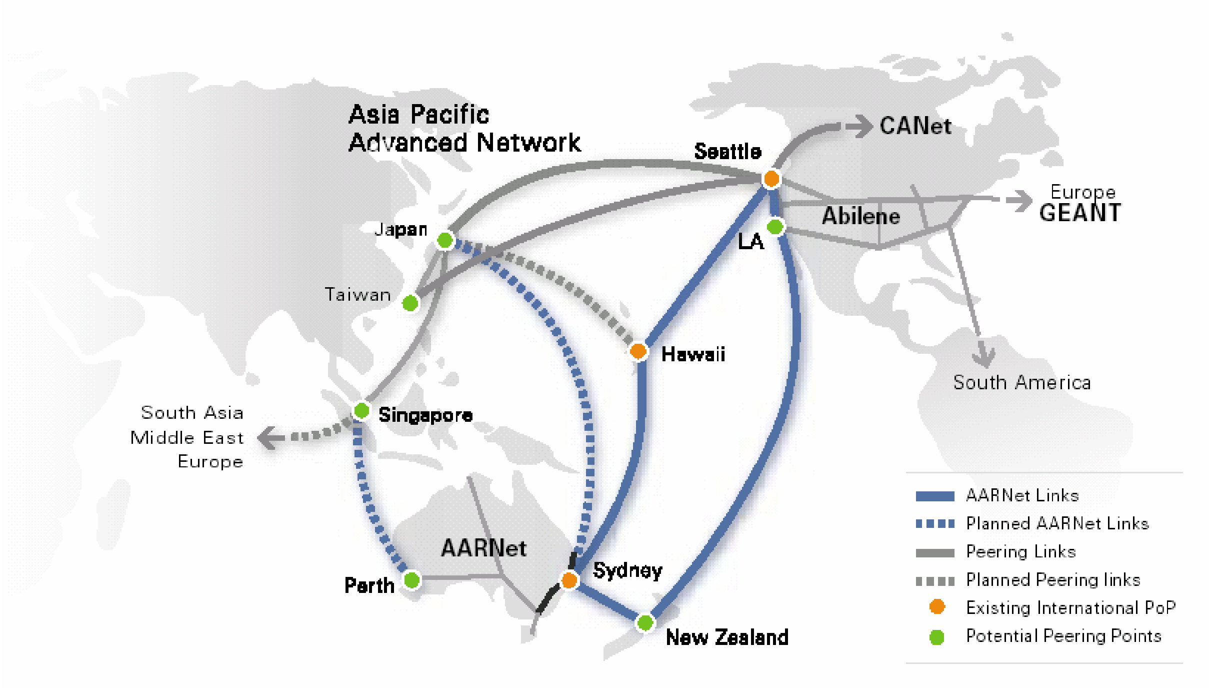


**Figure 5-3: AARNET International Backbone Network**

## 5.3.3 Combined federated battle labs

139. Combined Federated Battle Labs (CFBL) net is a 5 eyes + NATO secret Network that includes DSTO Fernhill and DSTO Edinburgh, and is believed to have an 8 mbps capacity. CFBL net supported Australian participation in the Joint Warfare Interoperability Demonstration (JWID) 2002 with Australian involvement being sponsored by Capability Systems – Information Capability Development. Unfortunately although it is a secret network, the presence of NATO means that Australia is only able to release unclassified information to this Network. For a variety of reasons it is planned to upgrade some parts of the Network to secret 4 eyes (AUS, UK, US, CA). This upgrade will include DSTO Fernhill and DSTO Edinburgh.

### 5.3.4 Coalition wide area network – allied

140. The Coalition Wide Area Network – Allied (CWAN-A) is a 5-Eyes accredited network sponsored by the US to provide a WAN environment where allied Nations can exchange classified information freely. The CWAN-A allows information transfer to the SECRET REL level. This WAN has been established primarily to support tactical and operational level information exchange. The size of the WAN changes to meet tactical and operational requirements, with Coalition LANs being added and removed as required.

# 6 GUIDANCE FOR BUILDING A DISTRIBUTED INTERACTIVE SIMULATION

## 6.1 DISTRIBUTED INTERACTIVE SIMULATION METHODOLOGY

141. DIS defines 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.

142. The basic Architecture concepts of DIS are[27]:

a. **No central computer controls the entire Simulation exercise**. 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**. As the User operates controls in the simulated or actual equipment, the Simulation is responsible for modelling the resulting actions of the entity using a Simulation Model. That Simulation is responsible for sending messages (or PDUs) 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 non-dynamic 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 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 receiving the entity state information 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.

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 must issue state updates for an entity. The dead reckoning Model represents the view of that entity by other Simulation

xxvii.[27] Source: Reference D.

applications on the network and is an extrapolation of position and orientation state using a specified dead reckoning algorithm. Simulations are not required to report the status of their entities as often.

### 6.1.1 Distributed interactive simulation protocols

*Note 12. The information provided in this section is largely taken from the IEEE 1278 DIS standard set.*

143. As discussed in Section 2, DIS operates by communicating entity information between Distributed Simulation computers via PDUs to create a Distributed Simulation. To increase functionality in the DIS Architecture, it is necessary to create new PDUs (as well as modifying the underlying enumeration sets). Therefore, each subsequent IEEE standard built in additional DIS functionality by increasing their respective PDU sets.

*Note 13. Common PDUs between the IEEE sets are essentially the same PDU format except for the Protocol version field, which is populated with the applicable DIS version number from Table 2-1. All Defence PDU Protocol version fields should be set to version 6 to minimise Interoperability issues.*

144. The IEEE 1278-1993 standard defined 10 PDU types:

**Table 6-1: IEEE 1278-1993 PDU Types**

| | |
|---|---|
| 1) Entity State | 6) Resupply Received |
| 2) Fire | 7) Resupply Cancel |
| 3) Detonation | 8) Repair Complete |
| 4) Service Request | 9) Repair Response |
| 5) Resupply Offer | 10) Collision |

145. The IEEE 1278.1-1995 Standard extended the above 10 PDUs giving the following 27 PDUs:

**Table 6-2: IEEE 1278-1995 PDU Types**

| | | |
|---|---|---|
| **A) Entity Information** | **D) Collisions** | 20) Data PDU |
| 1) Entity State PDU | 10) Collision PDU | 21) Event Report PDU |
| **B) Weapons Fire** | **E) Simulation Management** | 22) Message PDU |
| 2) Fire PDU | 11) Create Entity PDU | **F) Distributed Emission Regeneration** |
| 3) Detonation PDU | 12) Remove Entity PDU | 23) Emission PDU |
| **C) Logistics Support** | 13) Start/Resume PDU | 24) Laser PDU |
| 4) Service Request PDU | 14) Stop/Freeze PDU | **G) Radio Communication Protocol** |
| 5) Resupply Offer PDU | 15) Acknowledge PDU | 25) Transmitter PDU |
| 6) Resupply Received PDU | 16) Action Request PDU | 26) Signal PDU |
| 7) Resupply Cancel PDU | 17) Action Response PDU | 27) Receiver PDU |
| 8) Repair Complete PDU | 18) Data Query PDU | |
| 9) Repair Response PDU | 19) Set Data PDU | |

146. The IEEE 1278.1a-1998 Standard extended the above 27 PDUs giving the following 67 PDUs:

**Table 6-3: IEEE 1278a-1998 PDU Types**

| | | |
|---|---|---|
| **A) Entity information/interaction** | 23) Create Entity PDU | 44) Gridded Data PDU |
| 1) Entity State PDU | 24) Remove Entity PDU | 45) Point Object State PDU |
| 2) Collision PDU | **E) Distributed Emission Regeneration** | 46) Linear Object State PDU |
| 3) Collision-Elastic PDU | 25) Electromagnetic Emission PDU | 47) Areal Object State PDU |
| 4) Entity State Update PDU | 26) Designator PDU | **J) Simulation Management with Reliability** |
| **B) Warfare** | 27) Underwater Acoustics PDU | 48) Create Entity R PDU |
| 5) Fire PDU | 28) IFF/ATC/NAVAIDS PDU | 49) Remove Entity R PDU |
| 6) Detonation PDU | 29) Supplemental Emission/Entity State PDU | 50) Start/Resume R PDU |
| **C) Logistics** | **F) Radio Communications** | 51) Stop/Freeze-R PDU |
| 7) Service Request PDU | 30) Transmitter PDU | 52) Acknowledge R PDU |
| 8) Resupply Offer PDU | 31) Signal PDU | 53) Action Request R PDU |
| 9) Resupply Received PDU | 32) Receiver PDU | 54) Action Response R PDU |
| 10) Resupply Cancel PDU | 33) Intercom Signal PDU | 55) Data Query R PDU |
| 11) Repair Complete PDU | 34) Intercom Control PDU | 56) Set Data R PDU |
| 12) Repair Response PDU | **G) Entity Management** | 57) Data R PDU |
| **D) Simulation Management** | 35) Aggregate State PDU | 58) Event Report R PDU |
| 13) Start/Resume PDU | 36) IsGroupOf PDU | 59) Comment R Message PDU |
| 14) Stop/Freeze PDU | 37) Transfer Control Request PDU | 60) Record Query R PDU |
| 15) Acknowledge PDU | 38) IsPartOf PDU | 61) Set Record R PDU |
| 16) Action request PDU | **H) Minefield** | 62) Record R PDU |
| 17) Action Response PDU | 39) Minefield State PDU | **K) Live Entity** |
| 18) Data Query PDU | 40) Minefield Query PDU | 63) Time Space Position Information PDU |
| 19) Set Data PDU | 41) Minefield Data PDU | 64) Appearance PDU |
| 20) Data PDU | 42) Minefield Response Negative Acknowledgment PDU | 65) Articulated Parts PDU |
| 21) Event Report PDU | **I) Synthetic Environment** | 66) LE Fire PDU |
| 22) Comment PDU | 43) Environmental Process PDU | 67) LE Detonation PDU |

*Note 14. The IEEE 1278a-1998 standard is open to some interpretation in some areas. It is recommended that the reader refers to Reference N or consults with the DSTO (AOD) Advanced Distributed Simulation Laboratory for specific IEEE 1278a-1998 implementation guidance.*

147. Each of the defined PDU groups from Table 6-3 is briefly described below. More detailed information will need to be sourced from the standard.

### 6.1.1.1 Entity information/interaction

148. 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. 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. The visual appearance of an entity can be expressed in a number of ways. An entity 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.

149. Throughout a Simulation exercise, the state information associated with the interactions that take place between entities needs to be exchanged. Interactions that are currently supported include elastic and inelastic collisions. If two entities collide, the Simulations controlling the entities 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.

#### 6.1.1.2 Warfare

150. Warfare in a DIS exercise involves the firing and detonation of munitions. When an entity fires a weapon, the Simulation application controlling the entity needs to communicate the location of the firing weapon and the type of munition fired. The detonation of the munition is also communicated by the Simulation application controlling the munition. Using the information in the detonation message, all Simulation applications controlling effected entities assess damage to their entities. Note that chaff is treated similar to a munition: a Fire PDU is issued when the chaff is fired; Entity State PDUs are issued as the chaff travels; a Detonation PDU is issued when it explodes; and then, if relevant, Environmental PDUs are issued to describe its effect on the environment.

#### 6.1.1.3 Logistics

151. Repair and resupply logistic services are modelled in a Simulation exercise by means of the logistics PDUs. Messages representing requests for services and the transfer of supplies are exchanged between Simulation applications that are providers of the repair or resupply service and those simulated entities in need of such service. Note that these PDUs are designed for land warfare and are not believed to be used by any Australian DIS application.

#### 6.1.1.4 Simulation management

152. 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. A network manager would also have knowledge of host computers on the network, including their physical locations and network addresses. The network manager would perform analysis of network performance. Management of the overall Simulation exercise is also needed. Functions of Simulation management include starting, restarting, pausing, and stopping of an exercise; creating and removing entities from an exercise; and collecting and distributing data with Simulation applications. This standard includes Protocols for the best effort and reliable communication of these exercise management messages.

#### 6.1.1.5 Distributed emission regeneration

153. Representation of lasers, active electromagnetic emissions, and acoustic emissions, including active countermeasures are essential in certain Simulation exercises. Entities with emitters simulate their emitter and output Real-Time operational parameters. Receiving entities that have receivers can then regenerate the transmitted signal based upon the simulated emitter output data and stored database information. Each receiving entity is responsible for determining whether the emission is detectable. If so, the receiving entity will use the emission data to appropriately influence its detection equipment or Simulation of that equipment.

154. In addition, support is included to communicate information for functions such as cooperative interrogator friend or foe (IFF) systems, air traffic control (ATC) beacon and transponder systems, and navigational aid systems (NAVAIDS).

#### 6.1.1.6 Radio communications

155. 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 (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. These PDUs can also be used for transmitting Tactical Data Link messages (refer to Reference N).

#### 6.1.1.7 Entity management

156. As the size of DIS exercises continued to grow, mechanisms were developed 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 control of an entity from one Simulation application to another.

#### 6.1.1.8 Minefield

157. Minefields are a specific type of DIS entity that are encountered in certain exercises. A Protocol family has been specified in this standard to address the exchange of information about minefields and the mines contained therein. This exchange can be executed in either a heartbeat mode or in a query response Protocol mode. These PDUs were designed for land warfare, but could possibly be used to define an underwater minefield as well.

#### 6.1.1.9 Synthetic environment

158. For Simulation entities to participate meaningfully in the same exercise, they must have access to the same synthetic 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, including engineering effects such as the construction of a bridge, berm, or building; weapons effects, which could destroy objects created via engineering effects and 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 engagements, as well as day engagements, should be simulated.

#### 6.1.1.10 Simulation management with reliability

159. This standard supports a reliability service associated with each individual simulation management transaction. There are two reliability levels of service defined for use with the Simulation Management with Reliability protocol: an acknowledged service and an unacknowledged service. Simulation applications shall be able to interact at both reliability levels of service. The default reliability service for those simulation applications supporting the Simulation Management with Reliability protocol is the acknowledged service. The

Simulation Management with Reliability protocol may or may not be required for participation in an DIS exercise, depending upon the requirements of each exercise.

#### 6.1.1.11 Live entity

160. This standard supports application Protocols for field instrumentation applications associated with live participants on instrumented ranges operating within the DIS environment and interacting with simulated and real entities. Limited communication bandwidth, volume of data, methods of data transmission, and type of data transmitted are the principal drivers for the specific set of Protocols contained in this standard for use by live entities.

#### 6.1.1.12 Non-real time

161. Generally, since most DIS exercises operate with a human in the loop, Simulation time advances at the same rate as real-world time advances. As the scope of exercises using DIS expands, advancing time at a rate other than the rate at which real-world time advances is sometimes needed. The IEEE 1278.1a-1998 standard contains a specific Protocol that allows Simulation time to advance at a rate other than the rate at which real-world time advances. This Protocol does not introduce any new messages into this standard, but rather specifies how existing messages should be used to support the needs of non-real time applications. No Australian DIS application currently utilises the Non-Real-Time Protocol.

#### 6.1.1.13 Experimental protocol data units

162. PDU Type enumerations in the range of 129 through 255 have been reserved for experimental purposes.[28] This experimental PDU reservation allows the designer some flexibility to create new PDUs based on their specific Simulation application. For example, the FFG UP Project has adopted five BFTT PDUs and created 6 experimental PDUS to give a total of 11 experimental PDUs utilised (see Annex ). To allow for full Interoperability, it is recommended that these PDUs be converted to standard IEEE PDUs where possible.

### 6.1.2 Distributed interactive simulation enumerations

163. DIS provides a standard set of enumerations for entities and also for weapons, sensors communication devices, environmental descriptors and other attributes. This is a highly comprehensive set that includes virtually the entire US and former Soviet inventories, as well as those of other major nations such as Germany, France and the U.K. Each country has a unique identifying enumeration: eg Australia (13), USA (225), UK (224), and Germany (78). Compliance with those enumerations is mandatory for participation in a DIS exercise. Note that assets designed and/or built overseas must be included under the country to which a particular platforms' design is attributed. For example, the enumeration for HMAS Adelaide is interpreted as follows:

**Table 6-4: Enumeration for HMAS Adelaide**

| | |
|---|---|
| Kind | 1 for platform |
| Domain | 3 for surface |
| Country | 225 for US (country of design) |
| Category | 4 for guided missile frigate |
| Subcategory | 1 for Oliver Perry class |
| Specific | 58 for HMAS Adelaide |

xxviii. [28] The values in the range 0 –128 designate IEEE standard PDUs.

Where:

| | | |
|---|---|---|
| Kind | 0 | Other |
| | 1 | Platform |
| | 2 | Munition |
| | 3 | Life form |
| | 4 | Environmental |
| | 5 | Cultural feature |
| | 6 | Supply |
| | 7 | Radio |
| | 8 | Expendable |
| | 9 | Sensor/Emitter |
| Domain | 0 | Other |
| | 1 | Land |
| | 2 | Air |
| | 3 | Surface |
| | 4 | Subsurface |
| | 5 | Space |
| Country | The country to which a particular platform's design is attributed[29] | |
| Category | Provides Definition | |
| Subcategory | Provides Definition | |
| Specific | Provides Definition | |

164. A comprehensive listing of Australian enumerations is provided at Reference N.

## 6.2 SUPPORTING TOOLS

165. It is recommended that DSTO be consulted before using any DSTO or commercial tools. The following tools are available from commercial vendors.

### 6.2.1 Data logger tools

166. Data Loggers can record HLA and DIS Exercises and play them back for after action review. A recorded file can be played at speeds above or below normal, and areas of interest located quickly.

### 6.2.2 Viewers

167. Viewers provide two dimensional and three-dimensional views of the virtual world. This world can be viewed from the inside of a simulated moving vehicle or the viewpoint can be placed at another moving or stationary location.

### 6.2.3 DSTO tools

168. Tools developed within DSTO (AOD) for testing and analysing DIS systems include:

a. DIS PDU generator - generates PDUs of a specified type via a mouse click to stimulate DIS-compatible systems (see Section 9.1.2);

xxix. [29] Note the DIS country identifier for Australia is 13.

b. DIS Entity generator - generates entities (eg F18);

c. Maritime Entity Generator - generates a maritime entity - ship, submarine etc that can participate in a DIS exercise;

d. DIS Analyser - reads PDU stream and provides on-line analysis of PDU type, traffic stats etc. ; and

e. Moving Map display.

# 7 GUIDANCE FOR BUILDING A HIGH LEVEL ARCHITECTURE SIMULATION

## 7.1 HIGH LEVEL ARCHITECTURE METHODOLOGY

### 7.1.1 Functional view of the high level architecture

169. A functional view of HLA is shown in Figure 7-1[30]. A number of Federates may be brought together to create a common virtual, or synthetic environment. Some of these may be passive, such as data loggers and stealth viewers. These merely receive data transmitted over the network and analyse or visualise it. HLA enables event-stepped and time-stepped Federates to operate together and co-ordinates their time advances. Real time Simulations (such as DIS applications) may participate in the Federation, as may real equipment through an appropriate interface. Engineering Simulations, usually based upon the laws of physics, may also be integrated into the Federation Execution.

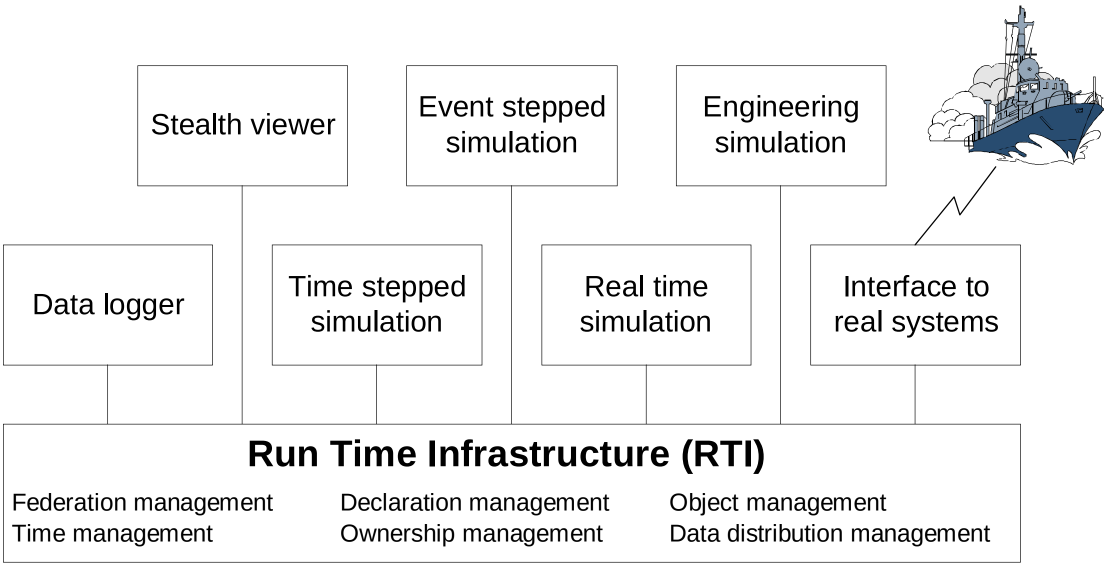


**Figure 7-1: Functional View of HLA**

170. As shown, HLA allows for a variety of implementations. Consequently, it is not defined by software but by three underlying components. These are the **Rules**, the **Object Model Template (OMT)**, and the **Interface Specification**. The HLA Rules describe mandatory characteristics of Federates and Federations required to facilitate reuse. The HLA OMT provides formalism for describing the exchange of data between the Federates. It can be thought of as a meta-model for all FOMs. The HLA Interface Specification describes the services provided by the RTI and its interface.

*Note 15. One important aspect of HLA is that it is designed to be independent of changes in software languages and networking technology. Generally, all that is required to implement a new technology is to define a new interface.*

xxx. [30] Source: Reference O.

### 7.1.2 Summary of the high level architecture rules

171. The rules for Federations are as follows[31]:

a. Federations shall have a HLA FOM, documented in accordance with the HLA OMT.

b. In a Federation, all Simulation-associated object instance representations shall be in the Federates, not in the RTI.

c. During a Federation Execution, all exchange of FOM data among joined Federates shall occur via the RTI.

d. During a Federation Execution, joined Federates shall interact with the RTI in accordance with the HLA interface specification.

e. During a Federation Execution, an instance attribute shall be owned by at most one joined Federate at any given time.

172. The rules for Federates are as follows:

a. Federates shall have a HLA SOM, documented in accordance with the HLA OMT.

b. Federates shall be able to update and/or reflect any instance attributes and send and/or receive interactions, as specified in their SOMs.

c. Federates shall be able to transfer and/or accept ownership of instance attributes dynamically during a Federation Execution, as specified in their SOMs.

d. Federates shall be able to vary the conditions (eg thresholds) under which they provide updates of instance attributes, as specified in their SOMs.

e. Federates shall be able to manage local time in a way that will allow them to coordinate data exchange with other members of a Federation.

173. Further detail on the HLA rules can be found in Reference H.

### 7.1.3 The high level architecture object model template

174. The data exchanged by the Federates are arranged in an object based Model or OMT. The data is classified as to whether it describes a persistent entity (known as an Object) or transient event (known as an Interaction).

175. An **Object** is typically a simulated physical entity that is persistent in a Simulation, such as a tank, or a plane, or a radio. Each object class is characterised by a set of **Attributes** describing its properties such as position and velocity. An **Interaction** is something that only lasts for an instant, such as a detonation, or a collision. Interactions are described by their **Parameters** that define the outcome of the event.

xxxi. [31] Source: Reference H.

176. Within the OMT is a set of tables for describing the above data. There is an **object class structure table** for listing the object classes in hierarchical order with their attributes and an **interaction class structure table** for listing interaction classes in hierarchical order with their associated parameters. Further detail on the development of an OMT can be found in Reference J.

177. The OMT is used to populate the SOM (or Federate Simulation) and the FOM (or Federation Simulation). These are discussed in more detail below.

#### 7.1.3.1 Simulation object model

178. Each Federate must have an associated SOM that describes its data requirements for entities. It provides a specification of the types of information that an individual Federate could provide to HLA Federations as well as the information that an individual Federate can receive from other Federates in HLA Federations (ie a sub set of the FOM with additional information on the object).

179. The SOM, in essence defines the capabilities a Federate is capable of providing and is described by the OMT. SOMs, similar to header files in C/C++, are an interface to the Simulation represented in a graphical form. The SOM can be used as a guide for the development of a FOM or vice versa.

#### 7.1.3.2 Federation object model

180. All the information that will be exchanged in a Federation must be documented in a predetermined FOM. The FOM can be considered to define the scope of the Simulation. Simulations in HLA must predetermine all the data they will be exchanging before the Simulation can take place.

181. To run a Federate using a certain FOM, a FED (for DMSO V1.3)/FDD(for IEEE 1516) file is required. There are also the OMT files which provide more in-depth information about a FOM and are necessary for tasks such as FOM mapping and FOM analysis. These files can be viewed in an Object Model Development Tool (see Section 7.2.1.2).

#### 7.1.3.3 Base object model

182. A **Base Object Model (BOM)** is a type of reference FOM. A BOM is like a subset of a FOM or a SOM. It is a re-useable HLA component that other FOMs/SOMs can be made up of. BOMs could be a quite valuable asset to the Simulation community. SISO is currently developing BOMs for general use (refer to www.boms.info). ADSO and DSTO will review BOMs for Australian use (see Section 3.7.1).

### 7.1.4 The high level architecture interface specification

183. The HLA Interface Specification describes the means by which Federates interact with the RTI.

184. The software that implements the interface specification is contained within the RTI and the application Developer makes use of it through the Application Programmers Interface (API). The two parts of the RTI interface are the RTI Ambassador and the Federate Ambassador (see Figure 7-2). The RTI Ambassador is a library that is linked into each Federate and facilitates communication from the Federate to the RTI. The Federate Ambassador facilitates communication from the RTI to the Federate. Although the interface to the Federate Ambassador is mandated, the Simulation Developer must construct the

internal details in order to implement the appropriate response to messages from the RTI. [32] The RTI functionality is further described in Section 7.1.4.1.

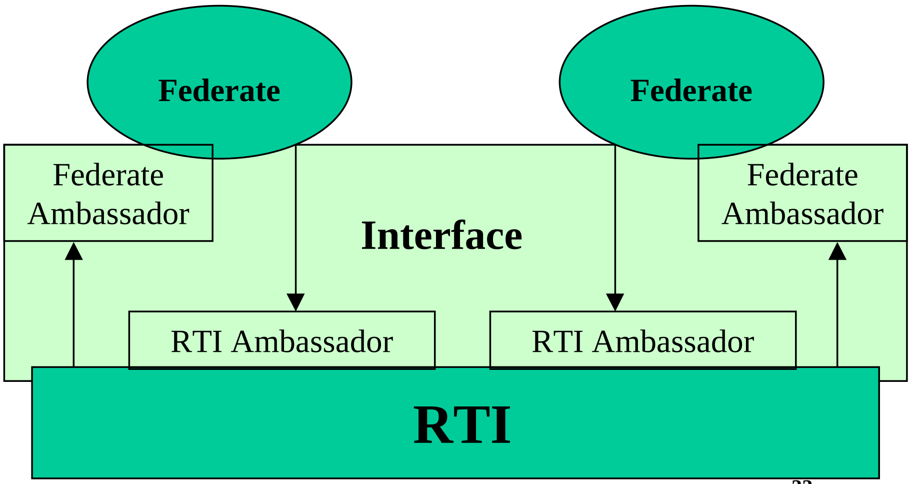


**Figure 7-2: Interfaces between RTI and Federates[33]**

185. Further detail on the Interface Specification can be found in Reference I.

#### 7.1.4.1 The run time infrastructure

186. The RTI's primary function is that of a data distribution mechanism (ie similar to a computer bus). The RTI enables participating Federates in a Federation to communicate with each other (see Figure 7-1) and does not store simulation information. The Federates store all of the simulation data and exchange information via the RTI through the processes of **publication** and **subscription**. Federates inform the RTI which attributes and parameters they allow other Federates to know about (publication), and which attributes and parameters they are interested in (subscription) (see Figure 7-3). The RTI also controls when Federates **join** or **resign** from a Federation.

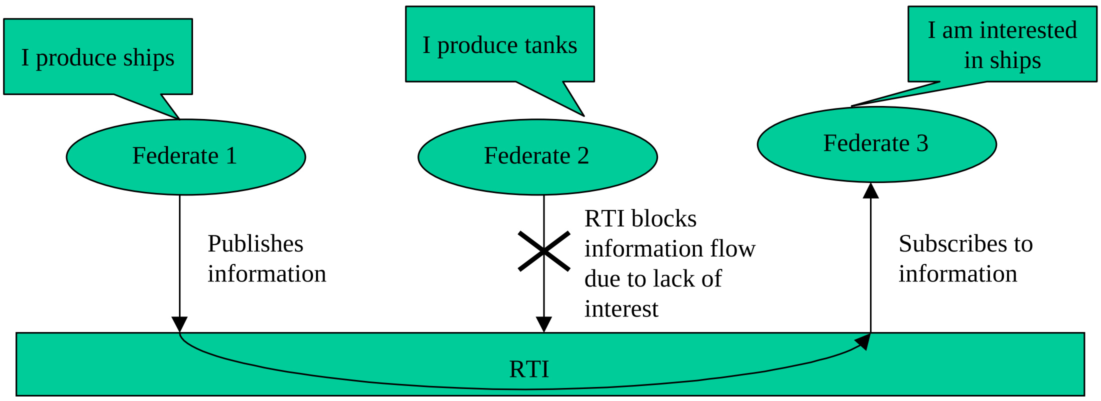


**Figure 7-3: HLA Publication and Subscription**

187. The common set of services provided by the RTI to the Federates can be divided into six categories:

a. *Federation Management:* Handles the creation, dynamic control, modification, and deletion of a Federation Execution.

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xxxii. [32] Source: Reference O.
xxxiii. [33] Source: Reference M.

b. *Declaration Management:* Enables Federates to declare to the RTI their desire to generate (publish) and receive (subscribe/reflect) object state and interaction information. Federates can subscribe to only the objects they want (or have the capability) to receive, eg Tanks might need only data pertaining to ground movement, or airplanes might need only data pertaining to flight activities.

c. *Object Management:* Enables the creation, modification, and deletion of objects and interactions. These services comprise most of the network traffic during run time.

d. *Ownership Management:* Allows Federates to transfer ownership of object attributes to other participants in the Simulation. This means that a single physical object represented within a Federate, such as a ship, may have ownership of its attributes distributed amongst a number of Federates.

e. *Time Management:* Provides useful services for setting, synchronising, and modifying Simulation clocks. Time Management services are tightly coupled with the Object Management services so that state updates and interactions are distributed in a timely and ordered fashion. HLA supports several time management methods such as Real-Time, scaled Real-Time, event-based time and as-fast-as-possible. These services support DIS time management approaches.

f. *Data Distribution Management:* Federates can provide conditions governing when to start or stop transmitting and receiving certain pieces of data.

188. DMSO in the past has supported the development of RTIs for free downloading as part of the US HLA program. Since 30 September 2002, this support has ceased and RTI development will only be undertaken on a commercial basis. The last version of the RTI that was supported by DMSO is version 6 of the RTI 1.3 Next generation (V1.3 NG6). However, due to shortfalls in this version and its predecessor, it is recommended that V1.3NG4 be used if required.

*Note 16. Defence holds the DMSO RTI under a license agreement. Although, the RTI may be used freely within Defence it may not be passed outside Defence. This means that contractors working with the DMSO RTI will need to conduct work on Defence premises.*

189. The choice as to which RTI to use in a Federation is very important. HLA defines an RTI API standard that federates use to communicate with other federates however the current HLA standard does not require different RTIs to interoperate. What kind of packets an RTI needs to exchange, how the packet is encoded, when and where it is sent and received, etc. have been left as design choices made by each RTI vendor and each RTI vendor has implemented these capabilities differently. This is proprietary information and is unlikely to be released into the public domain. Therefore a HLA developer must use interoperable (ie same vendor, probably same version) RTIs in every federate in the HLA federation.

190. The HLA developer must choose whether to use the DoD HLA 1.3 RTI API or the IEEE 1516.1 RTI API to maintain interoperability within the HLA federation. COTS HLA RTI vendors have different strategies to deal with 1.3 / 1516.1 interoperability issues – see Annex E.

191. The earlier 1.3 and 1516.1 RTI API standard definitions were ambiguous and each vendors implementation was slightly different and inconsistent. Even if a federate’s source code was available interoperability was never guaranteed by simply replacing one vendor’s

RTI toolkit with another vendor's RTI toolkit because of these API ambiguities. These ambiguities were removed with the approval of the SISO Dynamic Link Capability (DLC) RTI API (both 1.3 and 1516.1) in October, 2004. Any HLA application that is SISO DLC compliant (ie uses a SISO DLC compliant API to communicate with the DLC compliant RTI) can now switch between DLC compliant RTIs from different vendors. This occurs at run-time and application source code modification is not required. DLC compliant RTIs from different vendors will still not interoperate. However RTI ***interchangeable*** **COTS** DLC compliant HLA applications can now switch between DLC compliant RTIs so that all federates end up using interoperable versions of the same vendor's RTI and can thus achieve guaranteed, *wire standard* interoperability without the necessity for access to application source code.

### 7.1.5 The federation development and execution process

192. DMSO developed a Federation Execution Development Process (FEDEP) for developing and executing Federations to meet the needs of a Federation user or sponsor. The FEDEP (modified) was approved as an IEEE recommended practice in 2003 and known as IEEE 1516.3 (refer to Section 2.3.1). Figure 7-4 shows the seven basic steps that all HLA Federations should follow to develop and execute their Federations.

ADSO recommends that when creating Australian HLA Federations the FEDEP be used.

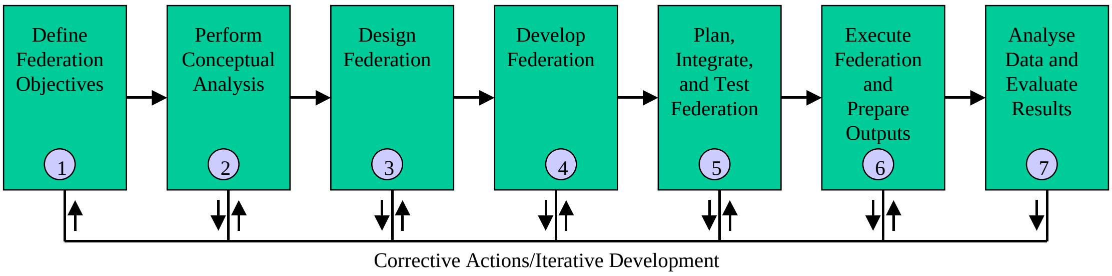


**Figure 7-4: FEDEP, top-level view[34]**

193. The seven steps in the process are briefly described below. The reader is referred to Reference K for further detail.

a. *Step 1:* **Define Federation objectives**. The Federation user, the sponsor, and the Federation development team define and agree on a set of objectives and document what must be accomplished to achieve those objectives.

b. *Step 2:* **Perform conceptual analysis**. Based on the characteristics of the problem space, an appropriate representation of the real world domain is developed.

c. *Step 3:* **Design Federation**. Existing Federates that are suitable for reuse are identified, design activities for Federate modifications and/or new Federates are performed, required functionalities are allocated to the Federates, and a plan is developed for Federation development and implementation.

d. *Step 4:* **Develop Federation**. The FOM is developed, Federate agreements are established, and new Federates and/or modifications to existing Federates are implemented.

xxxiv. [34] Source: Reference K.

e. *Step 5:* **Plan, integrate, and test Federation**. All necessary Federation integration activities are performed, and testing is conducted to ensure that Interoperability requirements are being met.

f. *Step 6:* **Execute Federation and prepare outputs**. The Federation is executed and the output data from the Federation Execution is pre-processed.

g. *Step 7:* **Analyse data and evaluate results**. The output data from the Federation Execution is analysed and evaluated, and results are reported back to the User/sponsor.

### 7.1.6 Further technical information

194. Further information on how to build HLA Simulations can be sourced from Reference M. For specific advice on how to install and run RTIs, build FOMs and install and run the supporting tools the reader is referred to Reference T. A range of HLA documentation is also available from https://www.dmso.mil/public/.

## 7.2 SUPPORTING TOOLS

### 7.2.1 High level architecture development tools

#### 7.2.1.1 SIMplicity

195. SIMplicity is an integrated development environment for Simulation Developers. It makes building and maintaining Simulations easier thus reducing project cost and duration.

196. The most obvious benefit of SIMplicity to novice HLA Developers is that it makes building HLA Simulations much easier due to the significantly reduced coding overhead.

197. Defence currently has 10 licences for use of the SIMplicity product. Please contact the DSTO Simulation Hub for further information regarding the SIMplicity licences.

#### 7.2.1.2 Object model tools

198. As HLA object models can be cumbersome to develop and share, automated tools have been created to develop, fill and share object models. Some of these tools are available from https://www.dmso.mil/public/ (ie Object Model Development Tool, Object Model Library and Object Model Data Dictionary) and commercial vendors.

#### 7.2.1.3 Planning federation execution

199. To support the FEDEP process a Federation Execution planners workbook has been developed, which provides a structured approach to compiling a Federation Execution. A number of automated tools have been developed to support this workbook and are available from https://www.dmso.mil/public/.

### 7.2.2 Viewers and dataloggers

200. See Section 6.2.

# 8 GUIDANCE FOR USING THE TEST AND TRAINING ENABLING ARCHITECTURE (TENA)

201. TENA is a domain specific, comprehensive architecture for testing and training range system development. It is seeks to give guidance to range developers and users on how to build range software systems that operate in all phases in a range event's lifecycle. It seeks to address the critical requirements of interoperability, reuse, and composability. TENA is primarily concerned with *how* to build range systems and gives only cursory guidance on *what* to build.

202. TENA has drawn from previous experience using:

a. the Range Commanders Council's Documentation System Process - a standard process for creating requirements and response documents for a range event;

b. the HLA Federation Development and Execution Process (FEDEP) process that focuses mostly on the steps necessary to create an HLA federation;

c. the Logical Range Process documented in the TENA Baseline Report; and

d. the FI 2010 (originators of TENA) Joint Overarching Requirements Document that recognised and corrected the problems in the TENA Baseline Report.

203. Although TENA is domain specific it addresses the complete lifecycle of a range event from several points of view when addressing what TENA can build and how it is done. These points of view are:

a. The TENA Logical Range Concept of Operations (ConOps) - Describes the lifecycle processes to be carried out to execute a range event and is discussed in section 8.1. For a more detailed discussion the reader is directed to section 2.2.3 of reference 123;

b. Building a TENA-Compliant Range Resource Application – Section 8.2 describes the relationships between the various TENA components (TENA Middleware, TENA Object Model, TENA Utilities, etc.) and how to build a TENA application; and

c. How the TENA addresses the relationship between the TENA Product Line (TENA applications, tools, utilities and gateways) and the TENA ConOps is discussed in Section 8.4.

## 8.1 BUILDING TEST AND TRAINING ENABLING ARCHITECTURE (TENA) EVENTS

### 8.1.1 The TENA Logical Range Concept of Operations

204. The TENA operational architecture view describes a technical concept of operations, the Logical Range Concept of Operations (the ConOps shown in Figure 8-1) derived from an analysis of many ranges' operational processes, on how to execute a range event using a logical range.

205. The TENA ConOps is similar to (ie has been built on the lessons learned from) the IEEE 1516.3 (2003) HLA FEDEP process (discussed in Sections 2.3.1 and 7.1.5) and the IEEE 1278.3 “Recommended Practice for DIS – Exercise Management and Feedback” (1996) standards.

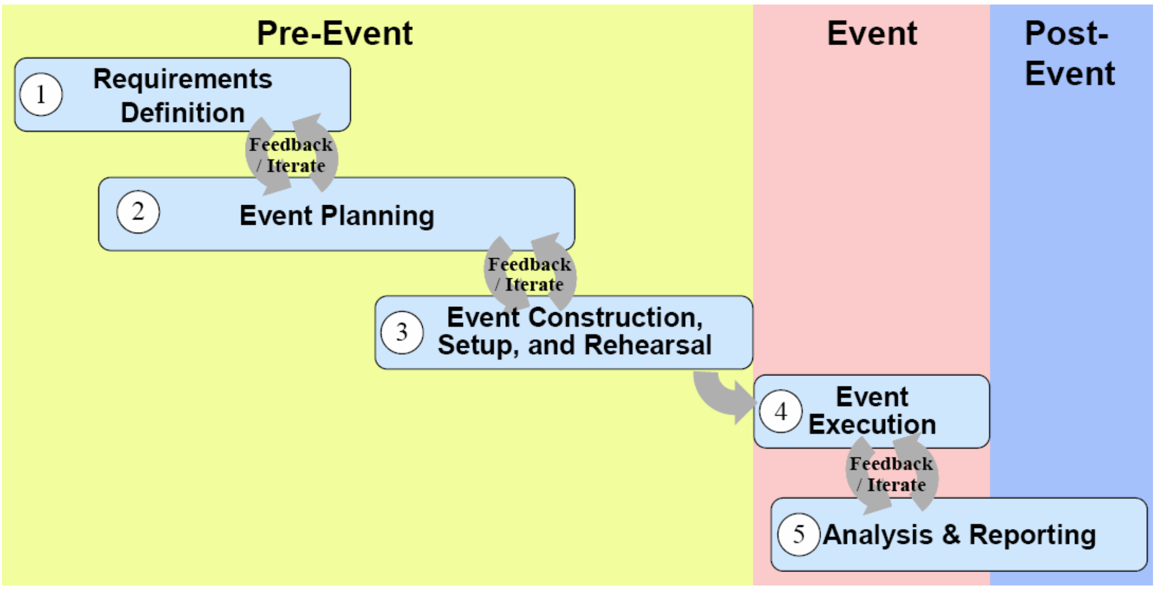


**Figure 8-1: Phases and activities in the TENA Logical Range ConOps**

206. Each TENA ConOps activity has a purpose, a list of information inputs, a group of participants who are key to completing the activity, a set of sub-activities (or steps) that may be highly inter-related and iterative in nature, and a list of products such as documentation, software, etc. TENA ConOps activities are performed in parallel, and the results of these activities may be fed back into the iterative work of other activities.

207. The processes required during Test and Evaluation events or training exercises are described in five main (simplified) phases or activities covering the complete range event lifecycle based on the TENA understanding of the logical range are:

a. Customer objectives and requirements analysis phase - The customer and event analyst work together, elaborating customer-defined requirements, to decide the overall purpose of the range event. The event analyst provides early feedback regarding feasibility of achieving the goals stated by the customer;

b. Event planning phase - Provides detailed plans for the event execution and time lines; scenario entities; range resources; analysis operations; data collection; event staffing and cost and schedule. The Event Planning Activity produces documents, not hardware or software;

c. Event construction, setup, and rehearsal phase - The logical range object model is defined, any range resource applications are upgraded to support this LROM, and the logical range configuration is integrated, tested, rehearsed, and made ready for event execution. The products of this activity are software applications, databases, and configurations of range resources;

d. Event execution phase - To execute the event based on the plans created in the event planning activity and with the range resources, databases and networks created and integrated in the event construction, setup, and rehearsal activity.

Monitored, managed, and controlled by the event controllers. Data is collected and some real-time/quick-look analysis is performed; and

e. Analysis and reporting phase - Provides detailed review and analysis of the event execution and the data collected during the execution. For a test event, the analysis provides answers to the fundamental questions that the test was designed to address, and fully achieve the customer's objectives. For a training event, a substantial amount of training value is received during the event execution activity itself; however, the analysis activity produces important feedback for both the training audience and the other event participants, thus enhancing the training value of the event. An After Action review is used to generate lessons learned from any problems and anomalies observed and hopefully solved during the event execution. This activity must provide access to distributed data for analysis, display, debriefing, replay, and reporting.

## 8.2 THE LOGICAL RANGE OVERVIEW

208. A Logical Range is defined as a suite of TENA resources, sharing a common object model, that work together for a given range event. TENA resources are applications that use the TENA Common Infrastructure for their communication and interaction. TENA resources can be:

a. Range applications that have been built to include the TENA Middleware and a set of TENA objects;

b. TENA tools and utilities configured for a particular event; and

c. Gateway applications, to bridge TENA systems to HLA, legacy range, or other protocols.

209. A logical range is a peer-to-peer linkage among TENA applications as shown in Figure 8-2.

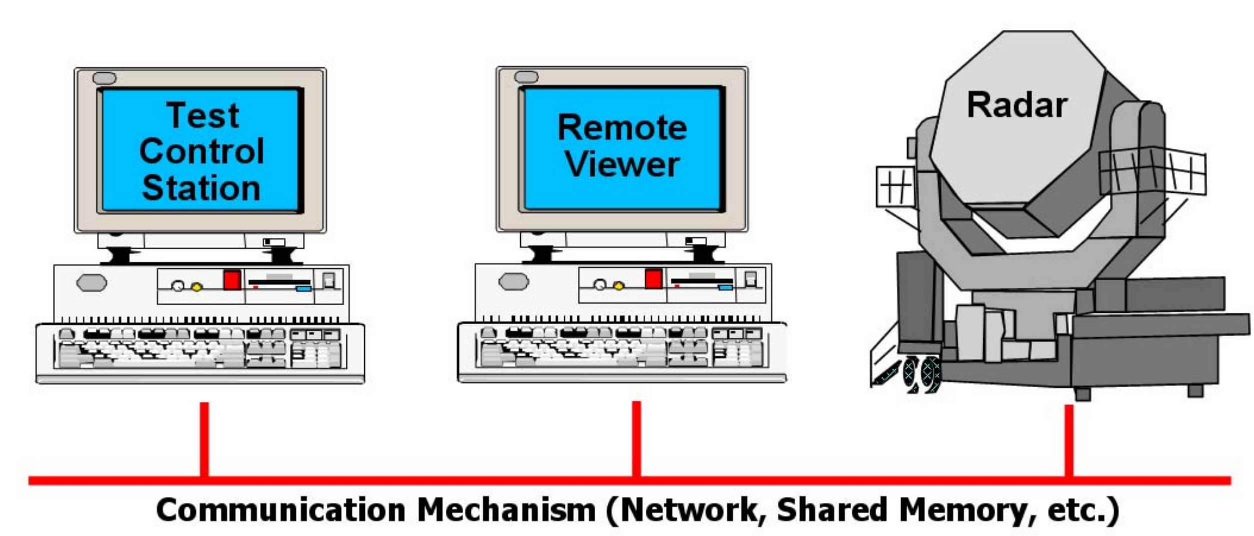


**Figure 8-2: A Peer-to-Peer TENA Logical Range**

### 8.2.1 The Logical Range Object Model

210. A Logical Range is a suite of TENA resources, sharing a common object model, that work together for a given range event.

211. A Logical Range Execution is a specific instance of this logical range running at a particular range for a particular range event.

212. The TENA Object Model (OM) provides the "common language" that all range resource applications use to communicate thus encouraging interoperability. The TENA OM will eventually encode all information communicated among range resource applications. TENA OM definitions may be similar in concept to (HLA) classes discussed in Section 7.1.3.

213. TENA Object Model definitions are described using the components available from the TENA meta-model. A meta-model is a description of the features available for use in formulating an object model.

214. The common object model shared by the TENA resources in a logical range is referred to as the Logical Range Object Model (LROM). A Logical Range Object Model (LROM**)** consists of those object definitions, derived from whatever source, that are used in a given logical range execution to meet the immediate needs and requirements of a specific user for a specific range event. The TENA LROM is conceptually similar to the HLA FOM (see Section 7.1.3.2). An LROM consists of object definitions selected from four levels of increasing standardisation:

a. Non-Standard – object definitions that are not in the other three categories defined below, but are defined solely for the purpose of a given logical range.

b. Candidate Objects **–** objects definitions, tested in several range events as part of many logical ranges, that have been forwarded to the TENA Architecture Management Team (AMT) as candidates for standardization.

c. AMT-Approved Objects **–** those object definitions, based on the appropriate candidate objects, that have been de-conflicted with other candidate objects by the AMT and have been approved for forwarding to the Range Commanders Council (RCC) for standardization.

d. RCC Standard TENA Objects **–** object definitions that have been approved as a standard by the RCC.

215. Some TENA Object Model class definitions from the US Joint National Training Capability (JNTC) Object Model (JOM – see Table 8-1) are shown in Figure 8-3. The EntityType class definitions show the parameters used to describe an entity are the exact equivalent of the information contained in the DIS IEEE 1278.1 Entity Type record and the IFFtransponderCode class definitions show that the IFF information of real interest are the actual IFF code values. Considerably more information is available in the DIS 1278.1a IFF PDU and the equivalent IFF part of the HLA Version 2 RPR-FOM but this information is (most likely) considered redundant in the JNTC Object Model.

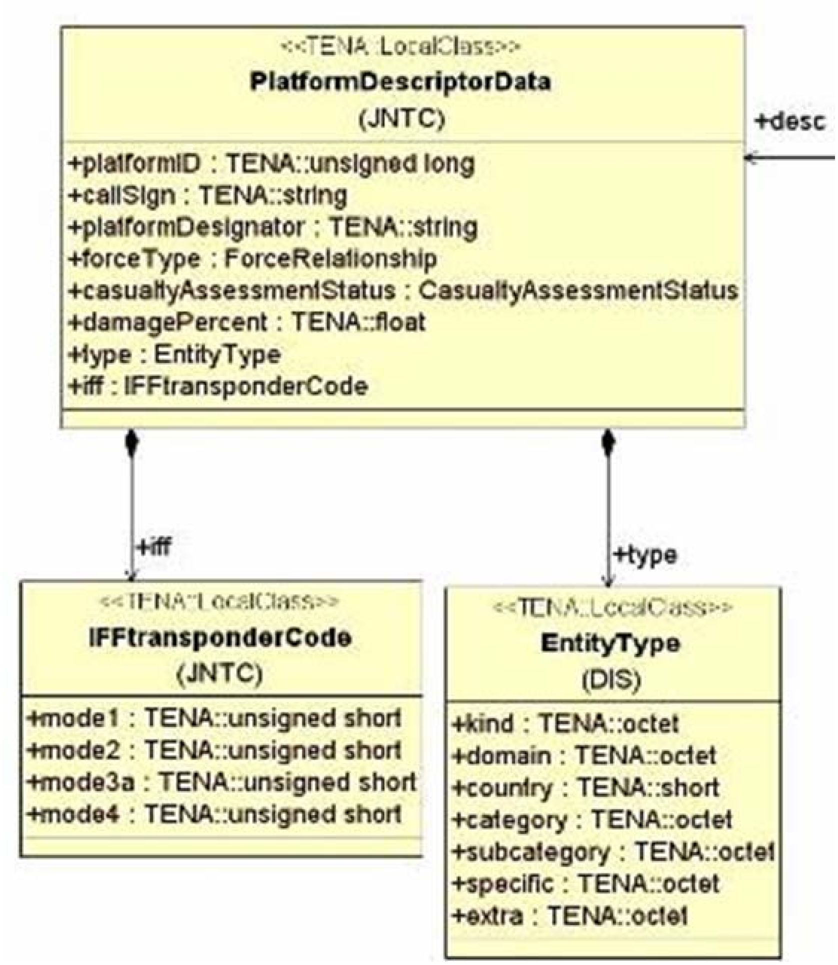


**Figure 8-3: Some TENA JOM LROM Object Model class definitions**

### 8.2.2 The TENA Middleware

216. The TENA Middleware is the high-performance, real-time, low-latency communication infrastructure used by range resource applications and tools during execution for all communication regarding objects in the Logical Range Object Model. It is linked into every TENA application along with the LROM object definitions as shown in Figure 8-4. The TENA Middleware is the communication mechanism for all objects in the TENA Object Model. The purpose of the TENA Middleware is to provide a unified application programmers interface (API) to support publish and subscribe messaging, data streams, and a link to the Logical Range Data Archive. It is functionally similar to the HLA RTI discussed in Section 7.1.4.1.

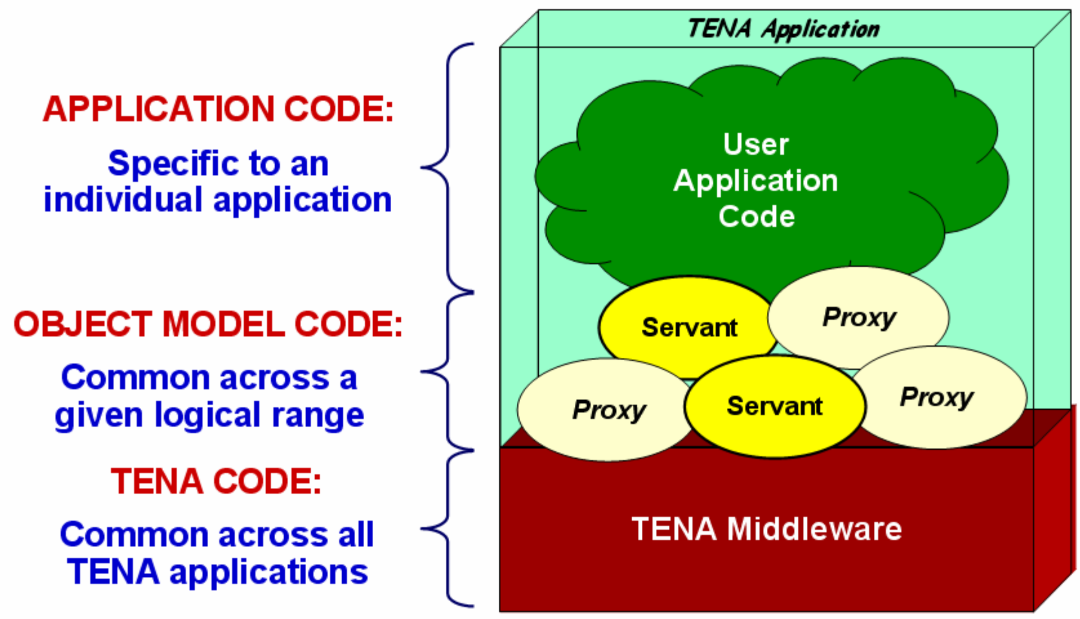


**Figure 8-4: Single TENA Range Resource Application**

217. The TENA Middleware must support numerous different communication media, such as conventional IP networks, shared memory, and reflective memory, but is not required to support all of these simultaneously.

218. Since the TENA Middleware must be linked into all range resource applications it must run on a wide variety of platforms and support a reasonable cross section of the programming languages used in the range community. It must also accommodate a wide variety of application threading and process management strategies, from single process, single threaded applications to multi-threaded re-entrant, and multi-process applications

219. The TENA Middleware API is a standard for all range resource developers to use when constructing their applications. The TENA Middleware API standardisation process is handled in a similar fashion to that of the TENA Object Model, first having to be approved by the AMT before being standardized by the RCC. The TENA Middleware must be designed to make interoperation with HLA simulations as transparent as possible.

220. Each application can act as both the producer (server) and consumer (client) of objects and data in a logical range. In their role as servers, applications serve TENA object instances that are called “servants.” In their role as clients, applications subscribe to TENA classes and are consequently given “proxies” by the TENA Middleware, each of which represents another application’s servant. In principle, both the server of a particular servant and the clients of that servant are able to update that servant’s state information. In practice, in almost all cases, only the servant’s server will update the servant’s state. Both servers and clients of a particular servant are able to invoke methods on the servant. The server invokes these methods locally; the clients invoke these methods remotely, via the proxy.

221. The range resource developer links his application, the TENA Middleware, and a particular LROM together into a single executable (see Section 8.3). TENA provides utilities to assist range resource developers make their applications work in a logical range context. The relationship between user written application code, the LROM objects, and the TENA Middleware representing the small peer-to-peer logical range shown in Figure 8-2 is shown in Figure 8-5.

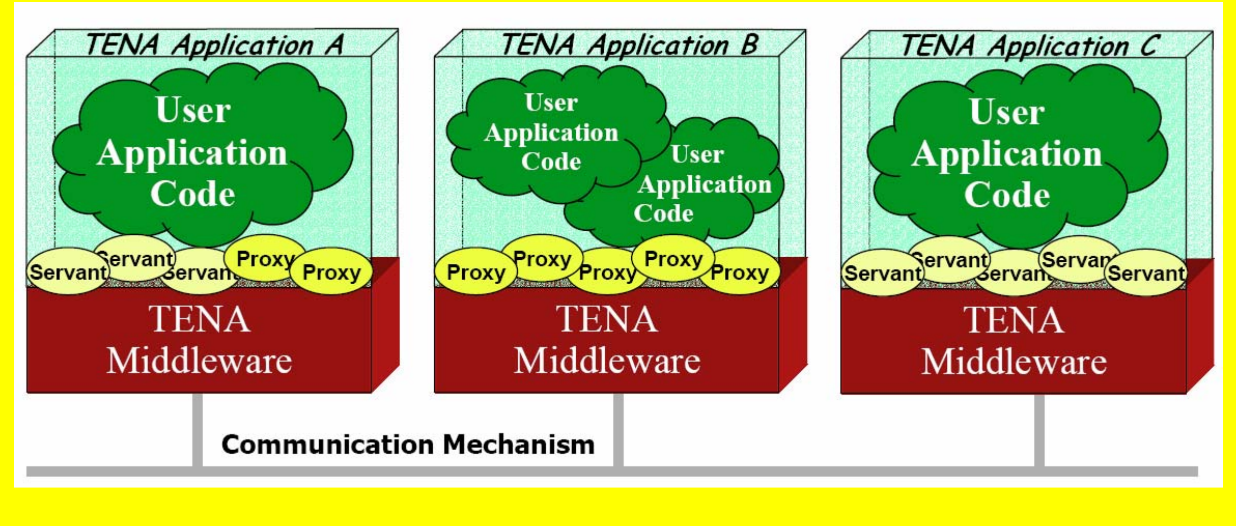


**Figure 8-5: A Small Logical Range**

## 8.3 PRODUCING TENA RANGE RESOURCE APPLICATIONS

222. The processes required to produce a TENA compliant logical range application are shown in Figure 8-6 where green represents code written by the range resource developers, yellow represents the LROM written by logical range developers, light blue items are either supplied by TENA, generated by utilities, or supplied with a particular computer system's development environment, dark blue items represent TENA Utilities, and red represents parts of the TENA Common Infrastructure. The process of making applications work in a logical range is one of re-designing (ie reusing) applications to work with the TENA Middleware and TENA Object Model and are as follows:

a. The range user creates his application code based on the functional requirements of his application;

b. The logical range developers create the LROM based on the interoperability needs of their logical range;

c. The range resource developer modifies his application based on the LROM object definitions, (either given to him by a logical range integrator, taken from the TENA Repository, or created specifically for his application) and writes the appropriate user code implementing the functionality needed to meet his range resource application's requirements;

d. The LROM object definitions are turned into coherent programming language source code by the TENA code generator, one of the Logical Range Object Model Utilities;

e. The user must supplement the LROM object definitions with LROM object implementations, the actual functionality behind the interfaces defined for a given LROM object;

f. Both the user application code and the LROM source code are compiled into object code using whatever compiler the user uses to create his application;

g. The resulting object code is linked with the TENA Middleware to create the executable application; and

h. In addition, the code generator creates the database schema needed for that logical range's Logical Range Data Archive, and the Logical Range Data Archive is itself created and initialized with this schema by the Data Archive Manager.

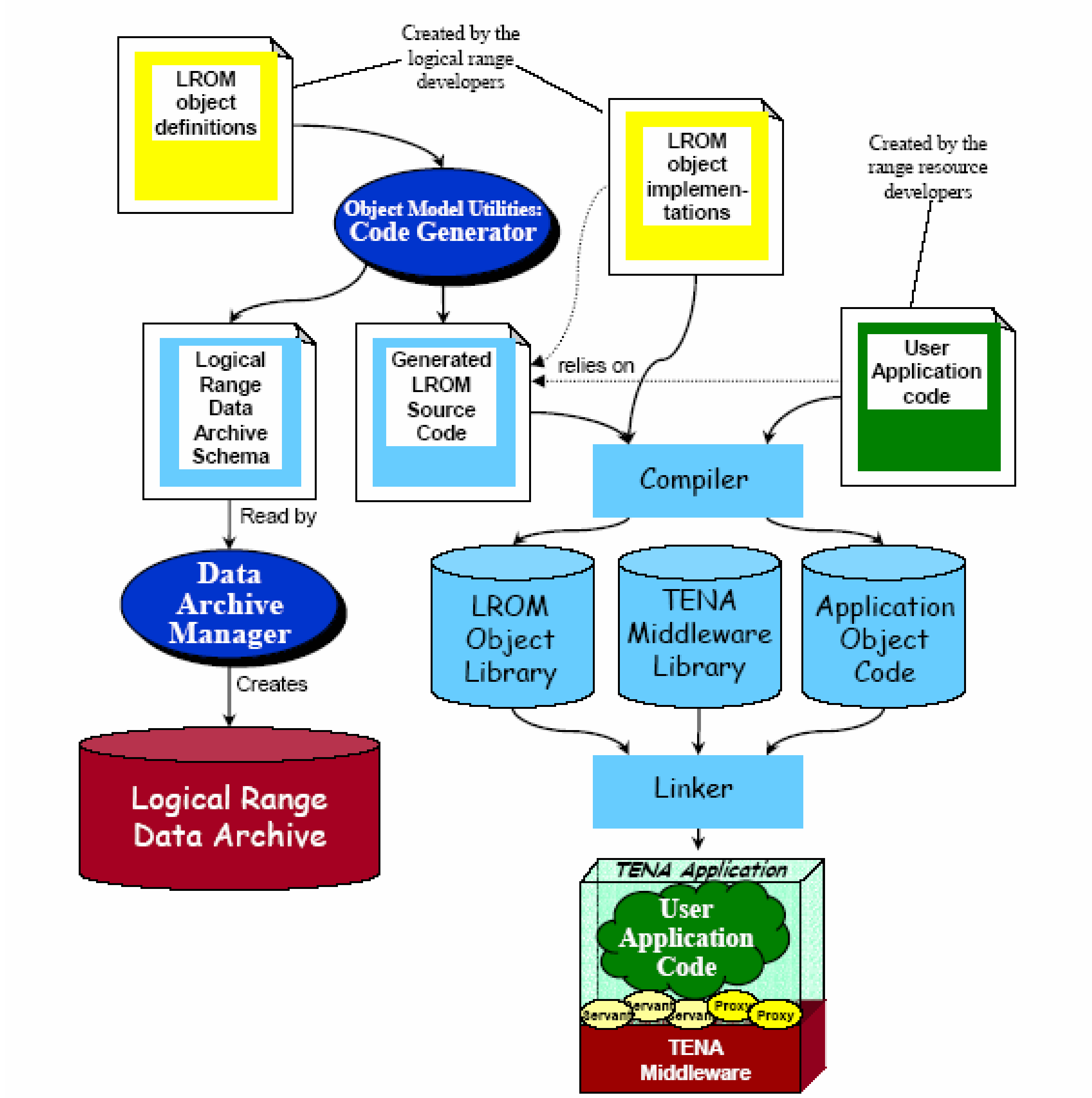


**Figure 8-6: Processes Required To Produce a TENA Compliant Logical Range Application**

223. Once an application has been compiled and linked it can be tested, verified, and validated. Changes to the user application code do not necessitate re-compilation of the objects in the LROM. Changes in objects in the LROM that a given application does not deal with will not necessitate re-compilation or re-linking of the application. Changes in LROM objects that a given application does deal with will necessarily mean that the application will need to be altered (to deal with the changed objects). In this case, both the LROM object definitions and the user application will need to be re-compiled and re-linked. This situation is no different from range operations where applications need to be changed and re-compiled to deal with new messages or data types introduced onto the range.

## 8.4 SUPPORTING TOOLS

### 8.4.1 TENA Range Resource Applications and Gateways

224. TENA range resource applications are generally used and tested in USA Joint National Training Capability range events. Some TENA range resource applications data relating to these JNTC events is shown in Table 8-1.

**Table 8-1: USA Joint National Training Capability TENA Related Event Data**

| Event | Date | TENA Version | Object Model | Applications / Reuse |
|---|---|---|---|---|
| MC-02 | July 2002 | 2.1 | MC-02 | 2 apps, 2 new |
| JCIDEX 03 | August 2003 | 3.X | JCIDEX | 6 apps, 1 reused, 5 new |
| HTE | January 2004 | 3.X | JOM | 9 apps, 6 reused, 3 new |
| CJTFEX | June 2004 | 4.0.3 | JOM | 15 apps, 5 reused, 10 new |
| Cope Thunder | August 2004 | 4.0.3 | JOM | 2 apps, 2 new |
| JRF-05 | March 2005 | 4.0.4 | JOM | 17 apps, 11 reused, 6 new |

225. Some TENA range applications used in recent US Joint exercises are shown in Table 8-2.

**Table 8-2: Some USA Joint National Training Capability TENA Range Applications**

| Application | Events | Description |
|---|---|---|
| TIER | MC02, HTE, CJTFEX, JRF | NAWC-WD range systems interface application and display |
| Rangeview | MC02, JCIDEX, THE, CJTFEX, JRF | Test range oriented display and analysis tool |
| ARDS | JCIDEX, THE, CJTFEX, JRF | Test and training instrumentation system interface |
| PCDS | JCIDEX, THE, CJTFEX | Air Guard training monitor, display and briefing tool |
| Air Warrior (TIER) | MC02, HTE | AF training instrumentation systems interface |
| NTC-IS (TIER) | MC02, HTE | Army National Training Centre instrumentation systems interface – DIS GW |
| IGRS | HTE | USMC instrumentation systems interface |
| GOTH | HTE, CJTFEX, JRF | TENA to HLA Gateway, TENA OM and FOM specific |
| CDL | JCIDEX, THE, CJTFEX, JRF | Engagement Adjudication workstation – “Common Data Link” |
| JTIDS IF (2 variants) | JCIDEX, CJTFEX, JRF | Tactical C2 messages system interface – DIS Signal PDU or Socket J GW |
| TACO | HTE, CJTFEX | Analysis monitor and display tool w/Patriot interface |
| WAM | CJTFEX, JRF | Analysis monitor and display tool |
| Static Tgt Gen | CJTFEX, JRF | Instrumentation simulator for non-moving, non-instrumented ground targets |

| | | |
|---|---|---|
| CGS | CJTFEX, JRF | UAV/JSTARS Moving Target Indicator (MTI)/ Fixed Target Indicator (FTI) |
| UAV | CJTFEX, JRF | Predator ground station TM and inst interface |
| ADOCS | CJTFEX | Army C2 messaging and database system |
| SureTrak | CJTFEX | Multi-source instrumentation interface and analysis – airspace monitor |
| TACTS GW | JCIDEX | Gulfport Air National Guard range ACMI instrumentation gateway |
| TENA-DIS | CJTFEX, JRF | TENA OM to DIS PDU translator for selected classes and PDUs |

### 8.4.2 The TENA Product Line

226. TENA has adopted a *Product Line* approach where the TENA Product Line comprehensively identifies the applications, tools, utilities and gateways that will be needed to support a Logical Range Event lifecycle. TENA Product Line applications, tools, utilities and gateways can be either (reusable) Commercial-Off-The-Shelf (COTS) or Government-Off-The-Shelf (GOTS). A TENA Tools Assessment Guide is available to guide assessment of TENA Product Line candidates.

227. There are four broad categories of applications in the Product Line Architecture: TENA Applications; TENA Tools; TENA Utilities; and TENA Gateways. The TENA Product Line has already been mentioned in Section 2.4.2 and is shown in Figures Figure 2-7 and Figure 2-8. The TENA Product Line is comprehensively discussed in the "TENA Tools Requirement Document" with the emphasis placed on TENA Tools and TENA Utilities.

228. The TENA Tools Suite provides for the setup, execution, control, and performance analysis of each Logical Range Execution. TENA Tools are TENA compliant applications that are used by Range Engineers for fundamental Logical Range capabilities of event planning, event management, communications management, and event analysis.

229. TENA Utilities support the user in making TENA work as an architecture, and include a Repository Manager, a Repository Browser, Logical Planning Utilities, a Logical Range Object Model Tool Suite, a Data Archive Manager, Data Collectors and a Replay Utility.

### 8.4.3 COTS Applications and Tools

230. MaK Technologies are currently testing the TENA extension to their VR-Link Toolkit. Because all the MaK Technologies applications are based on their VR-Link toolkit once testing of the TENA extension of VR-Link is completed all the MaK Technologies applications will be TENA enabled and able to be configured as TENA range resource applications.

231. MaK Technologies are about to release their new Interoperability Portal product that will (eventually) provide Gateway interoperability between DIS, HLA, TENA and Link-16 environments.

# 9 VERIFICATION, VALIDATION & ACCREDITATION OF DISTRIBUTED SIMULATIONS

232. Credibility is critical to the effective and appropriate use of Simulations when used independently or combined in a Simulation exercise. The cornerstone to establishing Simulation credibility is a robust Verification, Validation and Accreditation (VV&A) process. ADSO is currently developing a VV&A process for Defence Simulation, which will most likely be similar to that put in place by the US DOD. Refer to the DMSO Recommended Practices Guide for detailed information on this process (www.dmso.mil/public/transition/vva).

233. The Distributed Simulation community have defined three levels of recognised utility for Distributed Simulations:

a. **Distributed Simulation Compliance**: A Simulation/simulator that can send or receive Simulation information in accordance with the defined standard (eg IEEE 1278 for DIS and IEEE 1516 for HLA).

b. **Distributed Simulation Compatibility**: Two or more Simulations/simulators that are Compliant and whose Models and data that send and interpret Simulation information support the realisation of a common operational environment among the systems (ie, they are coherent in time and space).

c. **Distributed Simulation Interoperability**: Two or more Simulations/simulators that, for a given exercise, are Compliant and Compatible and whose performance characteristics support the Fidelity required for the exercise.

234. Distributed Simulation Interoperability is generally broken into two aspects:

a. The first is **technical Interoperability**, which addresses the capability of Simulations to physically connect and exchange data. This is the aspect of Interoperability which most people are familiar with and which the HLA and DIS frameworks address.

b. The second aspect of Interoperability is referred to as **substantive Interoperability**. It is focused on 'fair fight' and representational issues. While Distributed Simulation (eg HLA, DIS) technologies support Simulation inter-communication (ie technical interoperability), they do not guarantee substantive Interoperability.

ADSO recommends that all Simulations that are intended to be used for distributed applications are tested for Compliance as part of the development process. Distributed Simulation exercise sponsors should ensure during the Accreditation process that Simulations that are intended to participate in the exercise are sufficiently Compatible and Interoperable to fulfil federation objectives.

## 9.1 DISTRIBUTED INTERACTIVE SIMULATION VERIFICATION, VALIDATION AND ACCREDITATION

235. IEEE 1278.4 contains guidance for the VV&A of DIS exercises. The standard defines three levels of Simulation credibility for DIS Simulations:

a. **DIS Compliance**: A Simulation/simulator that can send or receive PDUs in accordance with the IEEE Standard 1278.

b. **DIS Compatibility**: Two or more Simulations/simulators that are DIS Compliant and whose Models and data that send and interpret PDUs support the realisation of a common operational environment among the systems (ie they are coherent in time and space).

c. **DIS Interoperability**: Two or more Simulations/simulators that, for a given exercise, are DIS compliant and DIS compatible and whose performance characteristics support the Fidelity required for the exercise.

236. Presently, the only non-paper based means to test the Compliance of DIS Simulations is via the DIS Test Suite (DTS) from the US PEO STRI and the DIS PDU generator from DSTO.

### 9.1.1 Distributed interactive simulation test suite

237. The DTS is a tool developed to test DIS compliance of Simulations and simulators. The latest version of the DTS is version 7.0 and can test IEEE 1278.1-1995 and IEEE 1278.1a-1998 PDUs. The DTS does not test the Fidelity of the Simulation but tests the ability to send, receive and interpret properly formatted PDUs. The DTS and advice on its use should be sought from DSTO (AOD). The DTS is governed by the US Arms Export Control Act, and is subject to limitations defined in US Government distribution agreements signed by AOD and the Maritime Warfare Training Centre Project. As identified in these agreements, the DTS is developmental in nature, and it has a number of technical limitations. For further information on the DTS see Reference P.

### 9.1.2 Distributed interactive simulation protocol data unit generator

238. A PDU generator has been developed by DSTO (AOD) which provides a source of PDUs of a given type for testing DIS Compliance. DIS 2.0.4, IEEE 1278.1-1995 and IEEE 1278.1a-1998 commonly used PDUs can be generated to test a DIS interface at the PDU level. The Model is written in Visual Basic and C++ interfaced to the MAK VRlink toolkit. The Model will be adapted to also output HLA objects using the RPR FOM. The tool can be used to test networks when a full simulator is not available and can also generate PDUs for testing which are not easily obtainable.

## 9.2 HIGH LEVEL ARCHITECTURE VERIFICATION, VALIDATION AND ACCREDITATION

239. VV&A guidance for HLA Federations is currently being developed by SISO and will be reviewed by ADSO for Defence use. This guidance will overlay the FEDEP

(discussed at Section 7.1.5), addressing overall VV&A methodology, roles and responsibilities, tasks, resulting products, and challenges.

240. HLA Interoperability is currently categorised into two broad areas (Reference U):

a. **HLA Technical Interoperability** – the capability of Federates to physically connect and exchange data in accordance with the HLA standard, and

b. **HLA Substantive Interoperability –** is driven by the needs of the Federation and has to be addressed by each Federation in a Federation specific way.

HLA Federate Compliance deals only with technical Interoperability. However this is a prerequisite for substantive Interoperability assurance.

*a. HLA Compliant simulations will only work together if: they use the same software implementation of the HLA, including the same RTI; they use the same description of data to be shared; and they agree on certain sequencing and timing issues.*

241. Presently, the capability to test technical Interoperability Compliance exists only in the United States, but this country is temporarily offering its support to its allies free of charge. For further information on HLA certification refer to Reference U.

### 9.2.1 The current US certification process

242. Compliance with HLA was mandated for US DOD Simulations in 1996 and reaffirmed in 1998. DMSO established a Federate compliance test process to evaluate Simulations and certify them as HLA Compliant to the HLA Rules, Interface Specification and the OMT. Testing began in October 1997 and as of November 2001 over 220 Federates have undergone HLA compliance testing. The process is described below. Additional information is available via the DMSO web-site and questions may be submitted to hla@dmso.mil.

243. The overall process is quite simple. To be certified as HLA Compliant, a Federate must demonstrate its adherence to the three specification documents defining HLA: the HLA Rules, the Interface Specification, and the OMT Specification. The current process has four steps outlined here.

**Step 1**: Complete a test application via test web page. Information needed to complete the application includes:

- Point of Contact Information
- Sponsorship Information
- Federate Name, Version, and Brief Description
- HLA Specification Version
- RTI Version (verified using DMSO RTI Verification process)
- Expected Interface Test Date

**Step 2**: The Federate developer submits a conformance notebook via the web site for the Federate under test, which is then tested by the certification agent. The conformance notebook consists of the following, ie a SOM, a Conformance Statement, and optionally, a Scenario File.

**Step 3**: Submittal of interface environmental data**.** The following information is requested, ie

- FOM (.FED or .FDD file)
- RTI Configuration File (RTI.rid file)
- API, Hardware, and Operating System used
- RTI Execution hostname and Internet (IP) address
- Federation Execution hostname and IP address
- Whether or not a firewall is in place
- Additional Comment Section

**Step 4**: Interface Specification & Reporting. The interface test requires the Federate under test to demonstrate every service and SOM capability in the predetermined test sequence, which is designed to represent a subset of the complete capability of the Federate. The Federate certification agent will log service data from the test, analyse the data, generate results, and return a certification summary report to the Federate developer. This report is the official record of HLA compliance for the specific version of the Federate code tested.

### 9.2.2 High level architecture certification issues

#### 9.2.2.1 Security

244. If a Model or any part of its supporting documentation (eg SOM) is classified, then it cannot be certified remotely through the Internet. It must therefore be tested either using a specific classified network or at a classified (remote) site. In either case the appropriate administrative issues will need to be addressed (eg security clearance); in addition, certification at a remote site will require the installation of a local version of the test suite (eg from a CD-ROM) on a computing resource provided by the Federate Developer. When the only classified part is the data (not including the SOM), it is still possible to supply unclassified data for testing purposes, provided that its design allows this operation (ie no classified data embedded in the code). This has been done many times within the US testing environment and in multinational Distributed Simulation experiments.

245. Another source of problem that can be related to security issues is the inability to open communication ports directly between the certification agent site and the Federate site. This is typically the case when a corporate firewall and global information systems security policy does not allow the required ports to be opened. In this case, either the certification must be done locally or the Federate moved to another site.

#### 9.2.2.2 Defence modeling simulation office certification

246. DMSO currently provides the HLA Federate compliance test on a no-cost basis for those who request it. Nevertheless, travel and shipping costs may be incurred by the Federate under test if conditions do not permit testing to be conducted on-line over the Internet, eg Due to network technical and/or security issues; it should be noted that these costs may be substantial. In addition, the US DoD currently makes no provisions for any special needs, which may be required by non-US Federates to achieve compliance.

It is planned that this compliance test capability will continue for as long as HLA is the selected architecture for Interoperability by the US DoD Service components. However, there is no guarantee that this service will be made available on a no-cost basis in the future.

## 9.3 TENA VERIFICATION, VALIDATION AND ACCREDITATION

247. TENA VV&A is achieved through TENA Compliance. Compliance with any architecture is a measurement of how much a given system follows its precepts and implements its policies. An application is compliant with the TENA architecture if it can communicate meaningfully about some subset of the objects in the standard TENA Object Model with other range resource applications and TENA tools using the TENA common infrastructure, fully participating in a TENA logical range throughout the entire logical range development and operation process. TENA provides a concept of operations, rules and standards to follow, a common object model, a common infrastructure, and tools and utilities to support the powerful logical range concept.

248. TENA specifies three different levels of compliance (shown in Figure 9-1) that an application can achieve and these are described as follows:

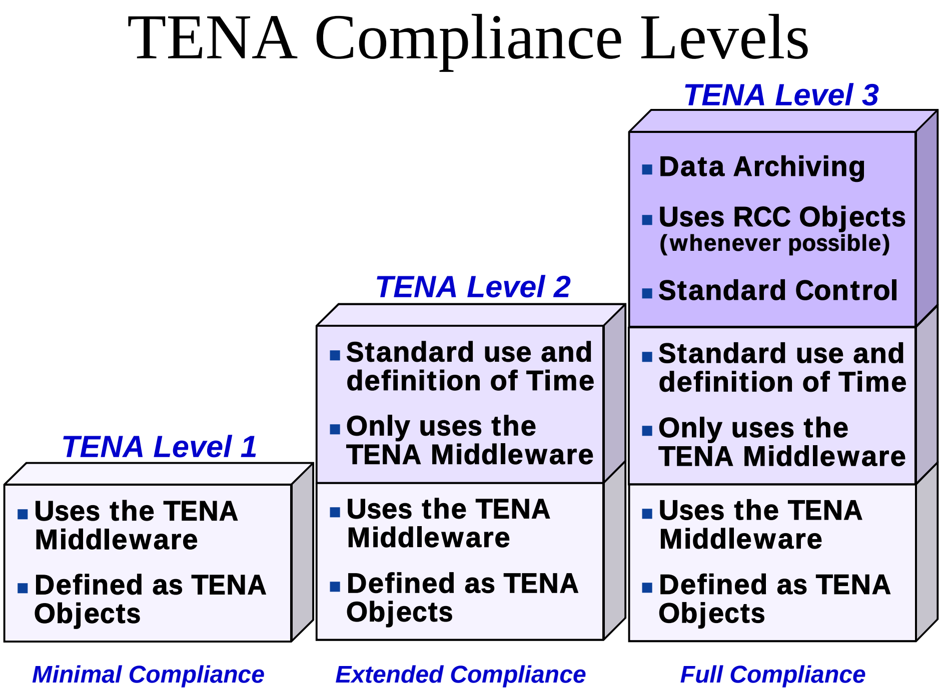


**Figure 9-1: TENA's Three Levels of Compliance**

### 9.3.1 Minimal Compliance:

249. The first level of (minimal) compliance represents just the minimum functionality that allows range resource applications to communicate at runtime using the TENA Middleware. While providing some interoperability, this level does not address many issues related to meeting the complete set of driving requirements.

250. Rules for Minimal Compliance

a. All range resource applications must interact with each other via the TENA common infrastructure using the standard TENA Middleware API - The TENA Middleware is the primary mechanism for enabling communication between applications during a logical range execution. Its interface must be standardized so that multiple independent application developers can all create interoperable (and by extension, reusable and composable) range resource applications.

b. Each logical range must have a logical range object model (LROM), specified in the standard manner that contains all of the object definitions that may be produced and consumed by all range resource applications in that logical range execution.

c. All objects in any LROM must conform to the TENA meta-model that describes what features an object may have (inheritance, composition, etc.)

### 9.3.2 Extended Compliance

251. The second level of (extended) compliance makes sure applications do not communicate using "back-door" mechanisms and that all runtime communication is done using the TENA Middleware. The requirement to document what object definitions applications are capable of dealing with helps enhance composability since this information can be made available in the TENA Repository for understanding and review by the whole community. Time is also treated in a standard fashion at this level so that incompatibilities do not arise over different representations or understandings of the passage of time.

252. Rules for Extended Compliance

a. All execution-time information exchange among range resource applications in a logical range shall be done using the TENA Middleware, as the standard mechanism for communication, with the information described in the LROM, the standard language for a given logical range. Thus these must be used, and only these must be used, in a logical range to achieve interoperability.

b. Every range resource application must specify in the standard format what information it has implemented to both produce and consume and the object implementations must adhere to the contract contained in their definition. TENA interoperability requires that the LROM object implementations actually perform the functions described in the object definitions.

c. All range resource applications are responsible for implementing the underlying functionality for measuring time by implementing the standard time-related interfaces provided by the TENA Middleware, and each application developer must document how their application implements time, including a description of the accuracy of the measurements. This common interface provides the necessary standardization to enable interoperability between all those applications that can get access to the correct time in some way, with each application's developer responsible for writing the code to retrieve the correct time via the standard interface.

### 9.3.3 Full Compliance

253. The final level of (full) compliance achieves all of the goals of TENA, as applications at this level are fully integrated into the standard TENA technical process. Fully compliant applications can be managed and monitored by the TENA Tools. They do not use

incompatible object definitions that might conflict with more standard applications. They use the Logical Range Data Archive for their persistent communication. The Logical Range Data Archive for these fully compliant applications becomes a full partner with the TENA Middleware for creating and maintaining interoperability, reuse, and composability, as well as the other driving requirements.

254. Rules for Full Compliance

a. All range resource applications must implement and publish a TENA Application Management Object as this is the mechanism for providing information about an application's state and function to enable a TENA application to be interoperable with the appropriate TENA Tools.

b. Range resource applications may not use an object definition that conflicts with an AMT approved or RCC Standard TENA object definition as part of a logical range object model as range resource applications must migrate toward using the standard definitions rather than retain the use of *ad hoc* definitions.

c. Range resource applications must use the Logical Range Data Archive (through its standard interfaces) for all data storage and persistent communication as the Logical Range Data Archive is responsible for communication between applications that may not be running at the same time.

255. While full compliance with the TENA architecture is the objective, compliance with any part of TENA can be valuable and it is simply not possible to require ranges to adopt all aspects of TENA immediately. Each facet of TENA brings certain capabilities, but not all facets need to be immediately adopted. However the more ranges embrace TENA and achieve TENA compliance, the more their systems will achieve interoperability, reuse, and composability. In particular, building new range systems will be less expensive and setting up range events will take less time, cost less, and provide more functionality to their customers. However the full benefits of TENA will only be evident to those applications and logical ranges that are compliant at the highest level.

# 10 DISTRIBUTED SIMULATION SUPPORT

## 10.1 TRAINING AND EDUCATION

### 10.1.1 High level architecture training

#### 10.1.1.1 University of Ballarat

256. The University of Ballarat currently runs a comprehensive introduction to HLA called 'A Short Course in the High Level Architecture (HLA)'. It has two parts, Part A – Introduction to the essentials of HLA and Part B – Design and Programming with HLA. For further information contact David Stratton, School of Information Technology and Mathematical Sciences, University of Ballarat on 03 53 279279 or d.stratton@ballarat.edu.au.

#### 10.1.1.2 Permian

257. Permian Pty Ltd runs a one day seminar on 'The High Level Architecture (HLA) – An Introduction'. The seminar provides an introduction to the architecture, including the terminology used within the Simulation industry. Design and implementation issues are considered, along with limitations of HLA. For further information, contact Permian on 08 8343 8423 or training@permian.com.au.

### 10.1.2 Distributed interactive simulation training

258. There are courses run on DIS by Distributed Simulation Technology Inc (DISTI) at www.simulation.com in the US (for example, A Practical Guide to DIS applications: a 4 day hands on course). DSTO (AOD) also has plenty of material on DIS (both documents and presentations) available.

## 10.2 SUBJECT MATTER EXPERTS

259. This section provides the details of the organisations in the Defence Organisation that have gained significant expertise in Distributed Simulation and its application. Simulation points of contact for these organisations can be found at Annex A of the Defence Simulation Manual (SIMMAN).

### 10.2.1 Defence Science and Technology Organisation

#### 10.2.1.1 Air Operations Division

260. The Advanced Distributed Simulation Laboratory within AOD continues to build expertise in Distributed Simulation while advancing the JOANNE Project (see Section 10.3.6). They also develop Distributed Simulation applications and can provide advice on a wide range of COTS Distributed Simulation tools.

#### 10.2.1.2 Maritime Operations Division

261. The Maritime Operations Division operates the Virtual Ship and Virtual Submarine (see Section 10.3.4) and has accumulated an expertise in building HLA based Simulations.

#### 10.2.1.3 Maritime Platform Division

262. Maritime Platform Division has accumulated expertise in HLA based Simulation. They are also managing the ongoing development of SIMplicity (see Section 7.2.1.1) and DSILI (see Section 3.7.2.3) tools.

#### 10.2.1.4 Command and Control Division

263. Command and Control Division has been involved in Distributed Simulation for the past decade. During this period C2D staff have used Protocols and specifications such as DIS and HLA. Currently they are utilising the Joint Semi-Automated Forces (JSAF) Simulation, which employs HLA as its underlying Architecture, and are using the SIMPlicity product for HLA code generation. A HLA based Simulation Architecture incorporating the Joint Theatre Level Simulation (JTLS) along with the ATTITUDE agent development tool and a JAVA based GUI has also been developed as part of the Course of Action Simulation environment (see Section 10.4.2).

#### 10.2.1.5 Land Operations Division

264. Land Operations Division operates the SERF (see Section 10.3.5) which uses DIS Virtual Simulation. LOD staff also employs One SAF and JSAF.

### 10.2.2 Army

#### 10.2.2.1 Army Simulation Wing

The Army Simulation Wing (ASW) was established to manage Army's Simulations and be responsible for their technical control. The ASW is directly responsible for the Army Synthetic Environment (see Section 10.3.1) which is based on HLA. Points of contact are:

### 10.2.3 Navy

#### 10.2.3.1 HMAS WATSON

265. HMAS Watson has accumulated considerable expertise in Navy Simulation training and the application of DIS for training. They operate the Bridge Simulator Trainer, and various ship combat systems Simulations. HMAS Watson is currently undertaking the development of the Maritime Warfare Training System (MWTS) (see Section 10.3.3). They have links to the US BFTT program through the CREAMS project.

### 10.2.4 Defence Material Organisation

#### 10.2.4.1 Maritime Systems Division

266. Major Surface Ships Branch has expertise in ship combat system Simulation and communication link Simulation, mainly focused on DIS.

#### 10.2.4.2 Aerospace Systems Division

267. The Aerospace Simulators Systems Support Office provides expertise on any matter relating to Aerospace Simulation.

#### 10.2.4.3 Land Systems Division

268. Land Systems Division provides Simulations for Army.

#### 10.2.5 Office of the Chief Information Office

##### 10.2.5.1 Australian Defence Simulation Office

269. ADSO has broad knowledge of Distributed Simulation and its application. ADSO are also sponsors for a number of studies and minors projects that involve Distributed Simulation.

## 10.3 PROJECTS CURRENTLY USING DISTRIBUTED SIMULATION

### 10.3.1 Army synthetic environment

270. The Australian Army is developing its Army Synthetic Environment (ASE) which has adopted HLA as its underlying Architecture. The ASE combines virtual and constructive systems within a common synthetic battlespace to provide tactical warfare training for Army units. The ASE uses a modified version of RPR FOM 1.0 with extensions to incorporate required Australian Army operational functionality.

### 10.3.2 Virtual air environment

271. The Virtual Air Environment (VAE) will provide a Distributed Simulation capability (currently using DIS) that will simultaneously support Live Simulation, Virtual Simulation and Constructive Simulation in support of Air Defence Ground Environment (ADGE) training objectives. The ADGE comprises the following elements:

a. an Air Operations Centre (AOC);

b. two Regional Operations Centres (ROCs), specifically EASTROC and NORTHROC – operated by 3CRU and 2CRU respectively;

c. one Mobile Sector Operations Centre (MSOC) – operated by 114MCRU;

d. one Jindalee Operational Radar Network (JORN) Coordination Centre;

e. multiple sensors (military and civilian microwave radars, OTHR radars and ESM systems);

f. external units, which could include any of nil to many instances of platforms such as fighter aircraft, naval ships, Airborne Early Warning & Control (AEW&C) aircraft, military air traffic control centres, civil air traffic control centres, and non-government agencies such as Coastwatch.

272. The aim of VAE is to allow AOC, EASTROC, NORTHROC, MSOC and JORN to:

a. collaborate in the same Simulation exercise,

b. collaborate with a subset of the ADGE members with either all or a subset of the remaining ADGE members being simulated by VAE,

c. perform a Simulation in isolation where either all or a subset of the remaining ADGE members are simulated by VAE, and

d. exclude themselves from the VAE environment so as to conduct operations based only on live data.

273. When operating in the VAE, each ADGE entity can participate in a Simulation independently of, or in collaboration with, other elements of the ADGE. Simulations may use either a combination of live and simulated data, or exclusively simulated data. Moreover, there may be multiple instances of the 'simulated and live' and/or 'simulated only' Simulations, depending on the collaborative configurations adopted by different ADGE elements. For example, EASTROC and MSOC may be operating in simultaneous, separate 'simulated only' sessions while NORTHOC and AOC are simultaneously collaborating in a combined 'simulated and live' Simulation. Alternatively, ADGE entities could be operating their own Simulations independently.

274. Where an entity does not participate in a Simulation but is required for the training mission described in the relevant Simulation scenario, the VAE is responsible for simulating that entity. This may include:

a. some or all of the other ADGE entities, and

b. some or all of the sensors and external units normally connected to the ADGE entity.

275. VAE is planned to extend and replace the present Surveillance and Control Group (SCG) interim Simulation capability. Unlike the interim Simulation capability, the VAE capability will support the full range of SCG's training requirements. An overview of the expected VAE capabilities is provided in Figure 10-1.

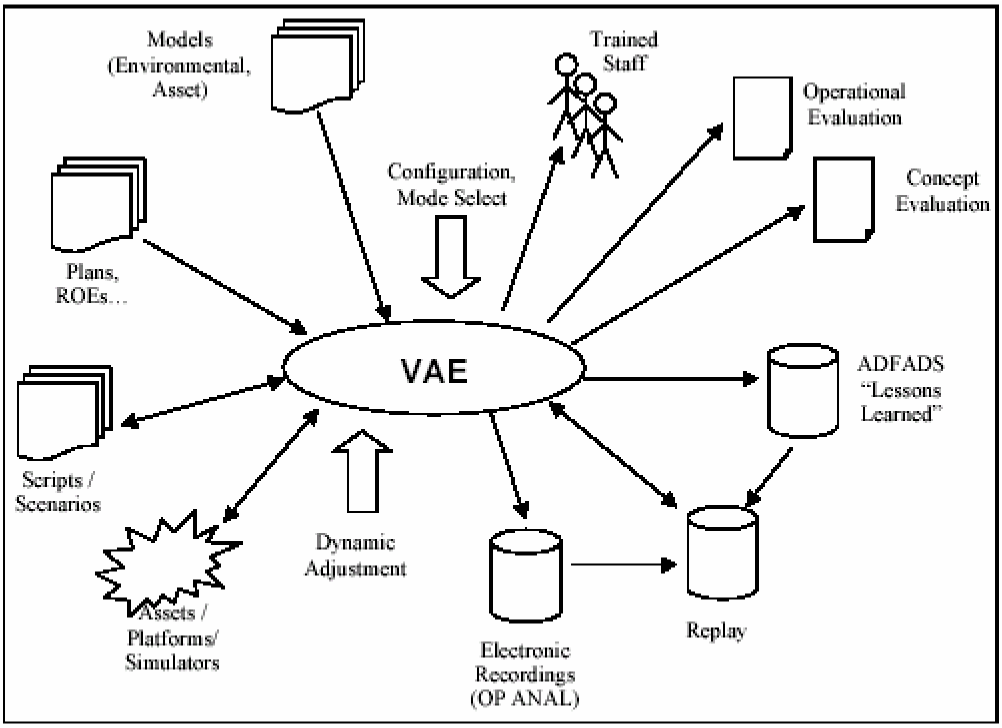

**Figure 10-1: VAE Capability Overview**

### 10.3.3 Maritime warfare training system

276. With the assistance of Project SEA 1412, the RAN is developing the Maritime Warfare Training System (MWTS) which initially links several existing operations room trainers to provide enhanced command team and tactical training for the RAN into the 21st century.

277. Phase 2 of the Project has integrated two legacy ships operations room simulators in the Maritime Warfare Training Centre (MWTC) at HMAS WATSON in Sydney, and has provided router facilities to communicate to simulations outside the MWTC. The simulators have been linked using IEEE 1278.1a-1998 protocols, and DIS compliant voice communication systems have also been installed. As of November 2003, work is ongoing to provide STANAG 5602 compliant Link 11 interfaces to these simulators, one of which merely emulates combat system functionality.

278. Later phases of the Project seek to establish an Australian wide-area maritime simulation network, which is planned to include ships alongside at Fleet Base East in Sydney and Fleet Base West in Western Australia, linked via their on-board training systems with the MWTC operations room models at HMAS WATSON, as well as other ADF simulators, such as RAN helicopter simulators and RAAF P3C, FA-18 and Airborne Early Warning & Control (AEW&C) simulators, all participating in a common virtual scenario. In time, there is potential to extend this environment to include ships at sea, although this requirement will create various communication challenges.

279. In the interim, Training Authority Maritime Warfare, through the MWTS Office, has commenced to develop operational concepts as well as training and assessment methodologies to optimise the training benefits of the infrastructure being provided. This work is being assisted by collaborative efforts with the US Navy as part of the CReaMS Project Arrangement.

280. This system will provide training for the two-ocean based Navy (Sydney and Perth) without requiring expensive co-location of assets. The MWTS would provide manned assets, instructor supervision, and game control and debriefing, for exercises involving both live and simulated assets across a large synthetic operating area. The Maritime Warfare Training System is depicted in Figure 10-2 below.

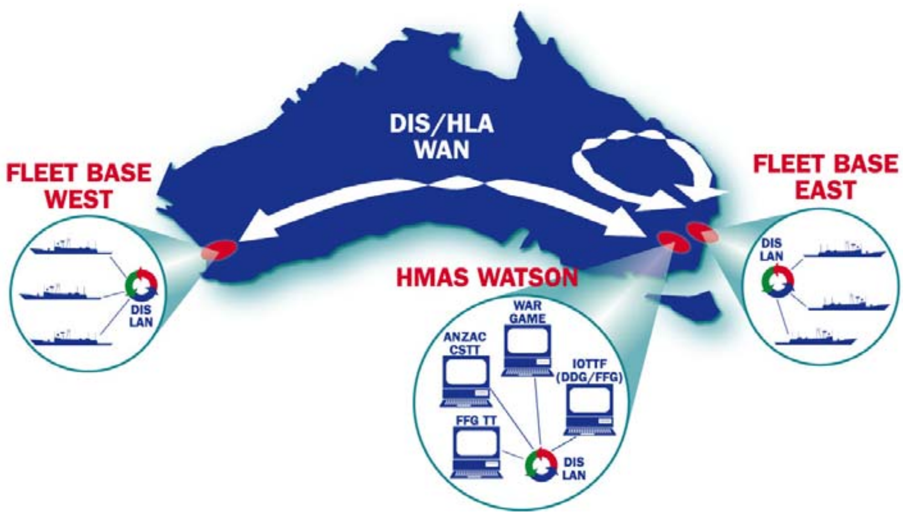

**Figure 10-2: MWTS Wide Area Network**

281. During later stages of the development of the MWTS, DIS connectivity will also allow linkages to other DIS-enabled Australian Defence Force (ADF) simulators such as the Seahawk simulator and P3C simulator (as examples), to participate in larger scale combined exercises over a wide area network (WAN) on an opportunity basis. Already, the distributed simulation capability provided by Project SEA 1412 has enabled the RAN to participate in international simulated exercises such as the CReaMS events (of which there have been three to September 2003).

282. The US Navy is developing the BFTT system that uses Distributed Simulation to provide training for individual and multiple sets of ships. BFTT is primarily an in-port, shipboard, combat system team training capability that operates by stimulating/simulating shipboard sensors and by introducing virtual forces such as friendly, neutral and hostile aircraft, ships and submarines.

283. It is essential that the MWTS be able to continue to interoperate with BFTT-enabled systems to enable maritime coalition training in a synthetic environment. BFTT is currently using DIS and will move to HLA when appropriate. At such a later stage, HLA capability could be added to allow Interoperability with external HLA-compliant systems. Thus later phases of the MWTS may run DIS internally on the HMAS WATSON LAN and communicate externally via HLA. DSTO (AOD) is cooperating with the USN BFTT program in outlining a collaborative research program on issues associated with migration from DIS to HLA.

### 10.3.4 Virtual maritime system

284. DSTO's Maritime Operations Division is coordinating a DSTO-wide R&D project to develop the Virtual Ship and Virtual Submarine. This project employs HLA as the core technology to connect modelled subsystems such as sensors, weapons, and C2 systems into an integrated Simulation of a naval vessel. Potential applications of the Virtual Maritime System include capability development, acquisition, training, mission rehearsal and tactical development. HLA compliant Simulation Models of sensors, weapons and command and control system components are currently under development.

### 10.3.5 Synthetic environment research facility

285. DSTO's Land Operations Division has established the Synthetic Environment Research Facility (SERF). Synthetic environments were built at RAAF Base Tindal, creating virtual cockpits with aircrew controls, instrumentation, and visuals, communications and data capture. This was supported by the creation of a virtual terrain and scenario generation integrated into real exercises. Army crews flew (Exercise Phoenix) a number of simulated-armed reconnaissance helicopter missions, as a learning exercise, resulting in significantly faster time-to-air capability while flagging critical issues.

286. The SERF is playing a crucial role in the support to Project Air 87 – the Australian Army's latest capability acquisition program - and the development of an Armed Reconnaissance Helicopter (ARH) capability. Using the SERF for virtual exercising, the Army is gaining vital information on ARH capability before delivery of the new aircraft in 2004.

### 10.3.6 DSTO's JOANNE project

287. DSTO has initiated the Joint Air Navy Networking Environment (JOANNE) Project, which will provide the technical Architecture to link the ADF's major training simulators into a synthetic environment for enhanced ADF training. JOANNE will provide guidance and standards for naval and air training simulators.

288. Project JOANNE is also an R&D test bed for Distributed Simulation that will benefit existing projects such as:

a. Navy's SEA 1412 Project which is developing the Maritime Warfare Training System (MWTS) by linking surface warfare trainers, On Board Training Systems and other ADF simulators to provide enhanced command team and tactical training (see Section 10.3.3), and

b. The RAAF's Virtual Air Environment (VAE) which aims to provide embedded training capabilities for the Australian Air Defence System through combining real and virtual systems, using Distributed Simulation to selectively stimulate operational systems (see Section 10.3.4).

289. JOANNE also addresses, through the Coalition Readiness Management System (CReaMS) Project Arrangement, connectivity to the US Navy's Battle Force Tactical Training (BFTT) Program.

#### 10.3.6.1 JOANNE research issues

290. Research issues address:

a. Simulator connectivity issues;

b. Interoperability via Distributed Interactive Simulation / High Level Architecture;

c. Assessment of the effectiveness of distributed training environments;

d. Database requirements for different systems to achieve common gaming area;

e. Scenario generation, exercise management, coordination, and control;

f. Use of Computer Generated Forces to enrich the training environment;

g. Interoperability among dissimilar systems; and

h. Network traffic and Latency issues.

#### 10.3.6.2 International collaboration: RAN/USN/DSTO

291. A Project Arrangement (PA) was initiated between DSTO and the US Navy for collaboration between JOANNE (Australia) and CReaMS (US). This PA was signed on October 10, 2001 by the Assistant Secretary of the Navy (Research, Development & Acquisition) for the US, and by the Counsellor Defence Science (Washington) for Australia. The PA aspires to enhance coalition Interoperability training and mission rehearsal capability. It will establish a virtual environment for coalition naval forces to conduct distributed testing, training, and education development that will be the foundation for future coalition mission rehearsal capability. The current PA expires at the end of 2003; a follow-on PA is under

negotiation between the RAN and USN that will progress this collaboration across the 2004 – 2007 time frame with a focus on training on the actual ship platforms (such as the FFG UP).

#### 10.3.6.3 Advanced distributed simulation laboratory

292. The Advanced Distributed Simulation Laboratory (ADSL) was established by DSTO to carry out R&D for JOANNE and VAE. The ADSL promotes the use of modular, cost-effective, commercial-off-the-shelf Distributed Simulation applications. The ADSL also draws upon the resources of DSTO's Air Operations Simulation Centre (AOSC) when medium to high Fidelity cockpits and display systems are required for experimentation.

## 10.4 PROJECTS PLANNING TO USE DISTRIBUTED SIMULATION

### 10.4.1 Joint simulation capability

293. The Joint Simulation Capability (JSC) offers a new, adaptive capability for Defence.

294. The mature JSC will enhance training, operational planning, capability development and experimentation for the Joint community. It will consist of new and existing Simulation systems and support, operating over the infrastructure provided by the Defence Information Environment (DIE). The JSC will be an adaptive capability that is beyond the capacity of any single Simulation. The JSC will give Defence the capability to link and network a suite of Simulations in a customised way, and then reform Simulations into different physical configurations to support the joint community as the demands upon them change.

295. To create this adaptive capability, the JSC requires five dimensions to co-exist (see Figure 10-3):

a. A strategic framework of strategy, policies, and standards to ensure the Simulation capability delivered matches the strategic and operational intent it serves,

b. A small tasking and coordination group to guide the integration of people, processes, Simulations, information technology and data to meet the strategic and operational requirements dynamically,

c. An information management system to ensure access to the right people and the right information to deliver an appropriate degree of Fidelity in the Simulation,

d. An assembly of Simulations which can be combined into a synchronised and coherent unity for a specific purpose, and,

e. A set of telecommunications, networks, Protocol services and other infrastructure to provide the connective tissue among the Distributed Simulations.

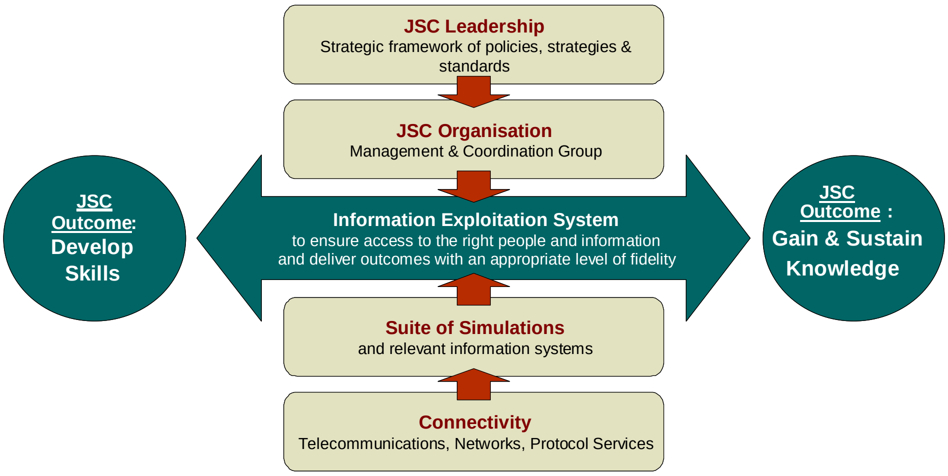


**Figure 10-3: Five co-existing dimensions are required to deliver the JSC outcomes**

#### 10.4.1.1 Performance objectives

296. The JSC will provide more coherence and consistency in the application of Simulation systems. It offers an effective and efficient approach to supporting the Joint community's requirements for operational planning, training and capability development. It will improve the quality of decision-making and better prepare the ADF for operations by:

a. Facilitating the combination of Simulations for greater effect in understanding and managing the complexity of planning for, and conducting, current and future operations.

b. Improving the management of information and data in Defence Simulations so that – through the use of common data sets – Users will gain greater confidence in the outputs of Simulation and their application in training and decision-making.

c. Allowing the reuse of Simulations and their underlying data and methodologies that also improves confidence in the Simulation outputs while concurrently reducing costs in developing and using Simulations.

d. Contributing to adequate through life support for Simulations and data to ensure systems are supportable and adaptable to the changing requirements in the Joint User community.

e. Facilitating VV&A of Simulations to ensure the Users have trust that Simulations will build critical skills or address safety critical issues realistically.

f. Maintaining Interoperability with the US to ensure Defence is able to leverage the close allied relationship for greatest mutual benefit in coalition operations, coalition training and experimentation.

g. Contributing to the achievement of the Defence vision for Simulation.

### 10.4.1.2 Initial Joint simulation capability

297. The JSC should initially comprise:

a. A minimum and essential set of policies and standards specific to the operation of the JSC,

b. A joint Simulation coordination group including a configuration management unit to develop, evolve and implement a joint Simulation Architecture with appropriate VV&A,

c. An initial information management system for Simulations including consistent data and metadata, to ensure timely access to the right information,

d. A select number of new Simulations, including hardware and software, to enhance decision support and training for ADF warfighting, and

e. A minimum investment in infrastructure such as network/Protocol services that are essential to the JSC and are not provided through the DIE investments. Essential facilities will include an Australian Strategic Warfare Analysis Centre in Canberra to test the people, plans and processes supporting joint warfighting, capability development and experimentation.

298. The primary Users of the JSC, initially, will be wholly AST and elements of VCDF and Strategy Groups together with elements of the Service and DSTO Simulation Environments. The initial boundary of the JSC is illustrated in Figure 10-4.

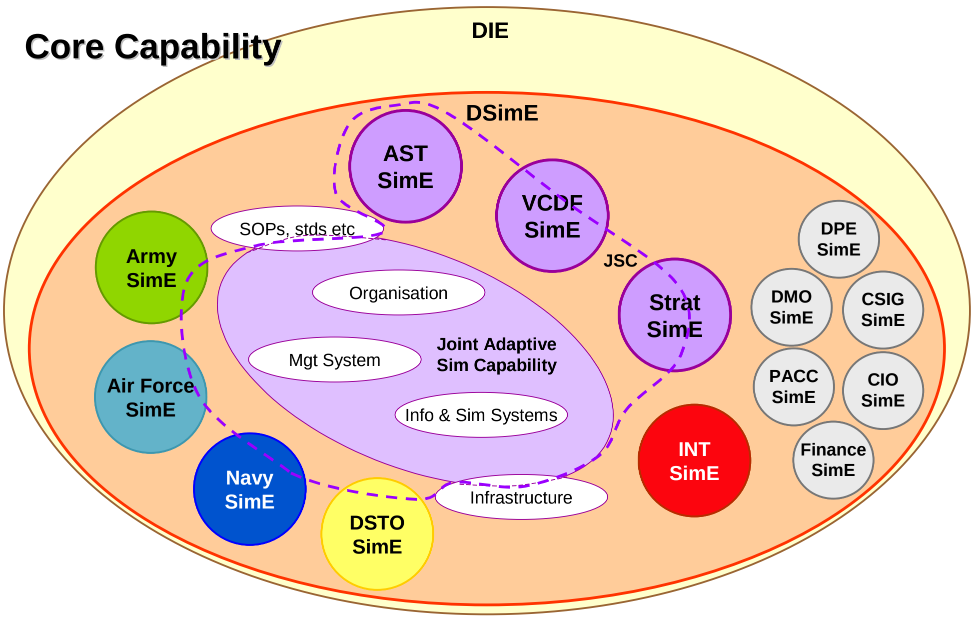


**Figure 10-4: Illustrative Initial Boundary of the JSC**

299. The distinctiveness of the JSC is the capability it provides Defence to link and/or network a suite of Simulations across the DsimE in a customised way, and then reform Simulations into different physical configurations to support the joint community as the demands upon them change.

### 10.4.2 Joint Combined Training Centre JP2098

#### 10.4.2.1 JCTC Vision and Objectives

300. Project JP2098 JCTC's vision is to provide enhanced high-end, bilateral training in order to increase and measure operational capability and preparedness, improve interoperability, and facilitate capability development. In pursuit of this vision, JP2098 is focused on three objectives:

a. delivery of an initial operating capability to support Ex Talisman Sabre 07;

b. meeting the US proof of concept requirements; and

c. demonstrating the value of continued investment in JCTC development.

301. The vision and objectives are supported by a high level operating concept.

#### 10.4.2.2 High Level Operating Concept

302. The high level operating concept underpinning JCTC development comprises four components including:

a. Provision of support to the planning and conduct of joint and combined training;

b. Independence from operational systems;

c. Support to specific use cases; and

d. Identification and focus on principle outcomes.

303. Support the planning and conduct of joint and combined training. JCTC aims to introduce capabilities which will be used by existing organisations to enhance the planning and execution of joint and combined training. Although there is a clear requirement for a coherent approach to joint and combined training, it is not within the scope of the JCTC project to instigate significant change.

304. Use Cases. The JCTC will support major ADF and multi-national training activities. This will include:

a. AS/US Joint Combined training (eg Exercise Talisman Sabre).

b. AS Joint training (e.g. the Vital and Northern Series)

c. The facilities, systems and procedures put in place by the JCTC will also support:

   i. AS Service combined training, notably with US forces (e.g. Pitch Black); and
   ii. AS single service training.

305. Principle JCTC Outcomes. The facilities, systems and procedures put in place by the JCTC include:

a. Facilities to support complex joint, combined and single service live training activities on SWBTA.

b. Network infrastructure to support simulation, exercise control and after action review activity.

c. The integration of AS joint and single service simulations, simulators and live instrumented forces into a single training environment.

d. Improved training objective tracking and feedback through automated data collection of training achievement.

e. In this context, the remainder of this document focuses on the simulation and support systems (SSS) elements of the JCTC.

#### 10.4.2.3 JCTC Functional Elements and Capability

306. The JCTC will comprise six key Functional Elements that provide the key capabilities of the system, being:

a. Training objective collection, analysis and feedback system.

b. Stimulation of real world C2 systems.

c. Provision of an EXCON Management Information system that provides “ground truth” for exercise control staff.

d. A synthetic training environment that enables live, virtual and constructive simulation components to interact and to stimulate training audience C2 systems.

e. A Joint Network that provides the hardware to support the above systems.

f. Facilities to support the above and to improve the conduct of live training at Shoalwater Bay Training Area.

307. The first five elements when combined comprise the overall functionality of the JCTC Training and Simulation and Support Systems (JCTC SSS).

#### 10.4.2.4 Mission System and Support System Structure

308. The JCTC Simulation and Support Systems component of JCTC comprises a Mission System and a Support System.

309. For JP2098 the Mission includes the design of any architecture, or dedicated hardware, software, networks, peripherals, processes and data needed.

310. The Support System is the organisation of hardware, software, materiel, facilities, personnel, data and processes required to enable the Mission System to be effectively operated and supported so that the Mission System can meet its operational requirements. The Support System embraces the support responsibilities undertaken by the ADO and in service support contractors and subcontractors.

### 10.4.3 Course of action simulation

311. Systems Simulation and Assessment (SSA) Group of Command and Intelligence Environments Branch, Command and Control Division (C2D) has a Course of Action Simulation (COA-Sim) R&D program that is exploring the applicability of Simulation to joint

military operations planning support. COA-Sim aims to provide an environment for planners to construct, modify and analyse a COA, or part-COA, consisting of a set of operational-level tasks.

312. COA-Sim contains Simulations that comprise of explicit behavioural Models in space and over time for own and opposing forces. This includes intelligent agents that represent doctrinal and standing operating procedures information that constitute task behaviour and Constructive Simulations (such as JTLS and JSAF) that represent the physical assets (platforms, sensors, weapons), see Figure 10-5.

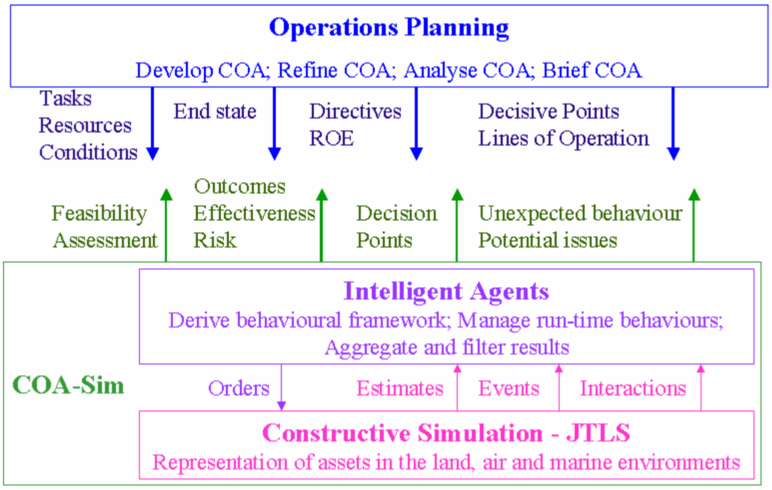


**Figure 10-5: Example roles of Simulation in support of planning.**

313. COA-Sim enables:

a. Computer tracking of a COA (the time and space motion of assets) and allows for back-tracking or fast-forwarding,

b. Exploration of the feasibility, effectiveness and risk of a single task through to an entire COA,

c. Exploration of logistics feasibility,

d. Wargame adjudication – provides representative outcomes,

e. Exploration of task synchronisation issues, and

f. Determination of decision points.

314. A key benefit of simulating a COA is to highlight unexpected behaviour or potential issues.

315. The key to COA-Sim is to ensure an efficient and effective interface with the operations planning environment. The COA-Sim environment contains a map of the geo-spatial region and asset locations, a planning support environment to ensure planners work at an appropriate level of abstraction and are not burdened with tactical or Simulation detail, and an order and behaviour support environment that supports staff operating the underlying Constructive Simulation, see Figure 10-6.

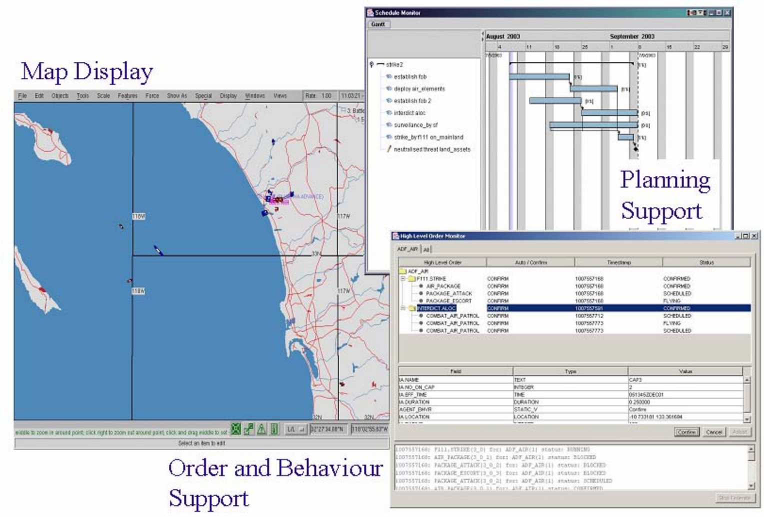


**Figure 10-6: Example COA-Sim environment interface.**

316. COA-Sim is a collaborative program between DSTO C2D and the Australian Defence Force Warfare Centre (ADFWC) Simulation Section. The ADFWC supports the operational-level of command through Simulation-based training and exercises. COA-Sim will draw from this existing experience and expertise. The COA-Sim program will inform development of Australian Simulation capability through the Australian Defence Simulation Office (ADSO).

# ANNEX A ABBREVIATIONS AND ACRONYMS

1. The table defines the acronyms and abbreviations used in the guide.

| **Acronym/ Abbreviation** | **Explanation** |
|---|---|
| AARNET | Australian Academic and Research Network |
| AdatP-34 | Allied Data Publication 34 |
| ADBOM | Australian Defence Base Object Model |
| ADF | Australian Defence Force |
| ADGE | Air Defence Ground Environment |
| ADSL | Advanced Distributed Simulation Laboratory |
| ADSO | Australian Defence Simulation Office |
| AMT | Architecture Management Team |
| AOD | Air Operations Division |
| AOSC | Air Operations Simulation Centre |
| API | Application Programmers Interface |
| ASE | Army Synthetic Environment |
| ASW | Army Simulation Wing |
| BFTT | Battle Force Tactical Training |
| BOM | Base Object Model |
| C3I | Command, Control, Communications and Intelligence. |
| C4 | Command, Control, Communications and Computer |
| C4ISR | Command, Control, Communications, Computer, Intelligence, Surveillance, and Reconnaissance |
| CCEB | Combined Communications Electronics Board |
| CFBL | Combined Federated Battle Labs |
| CIS | Comunication and Information Systems |
| COA-SIM | Course Of Action – Simulation |
| ConOps | Concept of Operations |
| COTS | Commercial Off The Shelf |
| CREAMS | Coalition Readiness Management System |
| CWAN-A | Coalition Wide Area Network – Allied |
| DIE | Defence Information Environment |
| DIE ATSL | Defence Information Environment Approved Technology Standards List |
| DIMPI | Defence Information Management Policy Instruction |
| DIS | Distributed Interactive Simulation |
| DMSO | Defence Modelling and Simulation Office (US) |
| DSILI | Distributed Simulation Infrastructure Library Interposer |
| DsimE | Defence Simulation Environment |
| DSTO | Defence Science and Technology Organisation |
| DTS | DIS Test Suite |
| DWACN | Defence Wide Area Communications Network |
| FI 2010 | US Foundation Initiative 2010 Project |
| FOM | Federation Object Model |
| GOTS | Government Off The Shelf |
| HLA | High Level Architecture |
| IEEE | Institute of Electrical and Electronics Engineers |

| | |
|---|---|
| IFF | Identify Friend or Foe |
| ISDN | Integrated Services Digital Network |
| JCTC | Joint Combined Training Centre |
| JNTC | Joint National Training Capability |
| JOANNE | Joint Air Navy Networking Environment Project |
| JOM | JNTC Object Model |
| JSAF | Joint Semi Automated Forces |
| JSE | Joint Synthetic Environment |
| JTLS | Joint Theatre Level Simulation |
| JWID | Joint Warfare Interoperability Demonstration |
| LROM | Logical Range Object Model |
| MILSATCOM | Military Satellite Communications |
| MOD | Maritime Operations Division |
| MPD | Maritime Platforms Division |
| MWTS | Maritime Warfare Training System |
| NATO | North Atlantic Treaty Organisation |
| NTMF (US) | Navy Training Meta-FOM |
| OBTS | On-Board Training System |
| OMT | Object Model Template |
| PDU | Protocol Data Unit |
| RCC | Range Commanders Council |
| RPR FOM | Real-Time Platform Reference FOM |
| RTI | Run Time Infrastructure |
| SEDRIS | Synthetic Environment Data Representation and Interchange Specification |
| SERF | Synthetic Environment Research Facility |
| SimE | Simulation Environment |
| SISO | Simulation Interoperability Standards Organisation |
| SOM | Simulation Object Model |
| SPG | Simulation Proposal Guide |
| TENA | Test and Training Enabling Architecture |
| TRM | Technical Reference Model |
| TRM FIG | Technical Reference Model Functional Interface Graphic |
| VAE | Virtual Air Environment |
| VV&A | Verification, Validation and Accreditation |
| WAN | Wide Area Network |

# ANNEX B DEFINITION OF TERMS

1. The table defines the Simulation specific terminology used in the guide.

| Term | Definition |
|---|---|
| Accreditation | The official certification that a Model or Simulation is acceptable for use for a specific purpose. |
| Acquirer | Those who procure simulations, with a focus on major and minor projects, including requirements analysis. They also administer the development of simulations. |
| Architecture | The structure of components in a program/system, their interrelationships, and the principles and guidelines governing their design and evolution over time. |
| Base Object Model | A single aspect of Federation interplay that can be used as a building block of FOMs and SOMs. |
| Constructive Simulation | In constructive Simulations individuals generally stimulate (make inputs to) the constructive Models but they are not directly involved in determining the outcomes of the Simulations. Constructive Simulations are used typically in situations, such as combat engagement Simulations for example, where participants seek to achieve a specified military objective given pre-established resources and constraints. They may also use engineering, cost and support Models. Examples include wargames, models and analytical tools. |
| Defence Information Environment | Is a complex and extensive collection of business-space and battle-space information systems. It encompasses vital Defence systems such as: communications, intelligence, surveillance, reconnaissance, electronic warfare and self protection, information operations, command and headquarters, and management, logistics, health and business systems. It includes Interoperability with allies, industry and other government agencies. |
| Developer | Those who develop simulations including design and programming. They not only build the initial base level capability, but all subsequent levels of capability as well. |
| DIS Compliant | A Simulation/simulator that can send or receive PDUs in accordance with IEEE Standard 1278 |
| DIS Compatible | Two or more Simulations/simulators that are DIS compliant and whose Models and data that send and interpret PDUs support the realisation of a common operational environment among the systems (ie, they are coherent in time and space. |
| DIS Interoperable | Two or more Simulations/simulators that, for a given exercise, are DIS compliant and DIS compatible and whose performance characteristics support the Fidelity required for the exercise. |
| Distributed Interactive Simulation | 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 IEEE 1278 compliant *Protocol Data Units* between distributed, computationally autonomous *Simulation* applications in the form of |

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| | *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 Simulation | A synthetic environment within which humans may interact through Simulations at multiple sites networked using compliant architecture, modelling, Protocols, standards and databases. |
| Distributed Simulation Compatability | Two or more Simulations/simulators that are Compliant and whose Models and data that send and interpret Simulation information support the realisation of a common operational environment among the systems (ie, they are coherent in time and space). |
| Distributed Simulation Compliance | A Simulation/simulator that can send or receive Simulation information in accordance with the defined standard (eg IEEE 1278 for DIS and IEEE 1516 for HLA). |
| Distributed Simulation Interoperability | Two or more Simulations/simulators that, for a given exercise, are Compliant and Compatible and whose performance characteristics support the Fidelity required for the exercise. |
| Federate | A member of a High Level Architecture Federation. All applications participating in a Federation are called Federates. This may include Federation managers, data collectors, real world (‘live’) systems (eg, C4I systems, instrumented ranges, sensors), Simulations, passive viewers and other utilities. |
| Federation | A named set of interacting Federates, a common Federation Object Model, and supporting Runtime Infrastructure, that are used as a whole to achieve some specific objective. |
| Federation Execution | The actual operation, over time, of a subset of the Federates and the Runtime Infrastructure initialisation data taken from a particular Federation. It is the step where the executable code is run to conduct the exercise and produce the data for the measures of effectiveness for the Federation Execution. |
| Federation Execution Data | Information derived from the Federation Object Model (class, attribute, parameter names, etc.). Each Federation Execution needs one. In the abstract, creation of a Federation Execution is simply the binding of a Federation Execution name to a Federation Execution Data. The organisation of Federation Execution Data will become the subject of standard so Federate Object Model tools can automatically generate them for any vendor’s Run Time Infrastructure. |
| Federation Object Model | An identification of the essential classes of objects, object attributes, and object interactions that are supported by a High Level Architecture Federation. In addition, optional classes of additional information may also be specified to achieve a more complete description of the Federation structure and/or behaviour. |
| Fidelity | The accuracy of the representation when compared to the real world. |
| FOM Agility | The ability to switch between FOMs with ease. |
| High Level Architecture | Major functional elements, interfaces, and design rules, pertaining as feasible to all DoD Simulation applications, and providing a common framework within which specific system architectures can be defined. |
| HLA Substantive | Is driven by the needs of the Federation and has to be addressed by |

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| Interoperability | each Federation in a Federation specific way |
| HLA Technical Interoperability | The capability of Federates to physically connect and exchange data in accordance with the HLA standard |
| Integrated Services Digital Network (ISDN) | A type of wide-area communication service provided by long-distance and regional telecommunications service providers. |
| Interconnectivity | The linking together of interoperable systems |
| Interoperability | The ability of systems, units or forces to provide services to and accept services from other systems, units or forces and to use the services so exchanged to enable them to operate effectively together |
| Latency | The time required for a device to begin physical output of a desired piece of data once processing is complete. |
| Live Simulation | Traditionally having a training focus, live Simulations represent military operations using military personnel and equipment in which simulated experiences are achieved using near-combat conditions. The advances of computer-based Simulation support is enriching this field, enabling real time data collection and exercise control, including the Real-Time insertion of Virtual Simulations to stimulate live responses (eg Computer controlled targets on live-firing ranges, EW threat / missile engagement scenarios). |
| M&S Interoperability | The ability of a Model or Simulation to provide services to and accept services from other Models and Simulations, and to use the services so exchanged to enable them to operate effectively together. |
| Manager | Those who manage a simulation or an organisation which uses or relies on simulation. |
| Model | A physical, mathematical or otherwise logical representation of a system, entity, phenomenon, or process |
| Modelling and Simulation | The use of Models, including emulators, prototypes, simulators, and stimulators, either statically or over time, to develop data as a basis for making managerial or technical decisions. The terms 'modelling' and 'Simulation' are often used interchangeably. |
| Necessary Bandwidth | For a given class of emission, the minimum value of the occupied bandwidth sufficient to ensure the transmission of information at the rate and with the quality required for the system employed under specified conditions. Emissions, useful for the good functioning of the receiving equipment as, for example, the emission corresponding to the carrier of reduced carrier systems, shall be included in necessary bandwidth. |
| Protocol | A set of rules and formats (semantic and syntactic) that define the communication behaviour of Simulation applications. |
| Protocol Data Unit | Distributed Interactive Simulation terminology for a unit of data that is passed on a network between Simulation applications. |
| Real World | The set of real or hypothetical causes and effects that Simulation technology attempts to replicate. When used in a military context, the term is synonymous with real battlefield to include air, land, and sea combat. |
| Real-Time | In Modelling and Simulation, simulated time advances at the same rate as actual time; for example, running the Simulation for one second results in the Model advancing time by one second. Contrast with: fast time; slow time. |

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| Router | A device or system used to connect separate LANs and WANs into an internetwork. It also routes data traffic between the networks after selecting the transmission path or paths. Routers were called gateways during the early years of Internet development. |
| Run Time Infrastructure | The general purpose distributed operating system software that provides the common interface services during the runtime of a High Level Architecture Federation. |
| Simulation | The implementation or exercise of a Model over time. |
| Simulation Environment | Simulations and the operational technical environment that surrounds them. It includes:<br>a. simulation entities, terrain, atmospheric, bathyspheric and cultural information; and all the conditions, circumstances; and<br>b. influences surrounding and affecting simulation entities including those stated in a. |
| Simulation Object Model | A specification of the intrinsic capabilities that an individual Simulation offers to Federations. The standard format in which SOMs are expressed provides a means for Federation developers to quickly determine the suitability of Simulation systems to assume |
| Simulation Proposal Guide | A document designed to assist developers of Simulation proposals, and those reviewing and assessing those proposals, to establish clearly how the Simulation will enhance capability, save resources or reduce risk to develop, train for, prepare for and test military options for Government. |
| Simulator | 1. A device, computer program, or system that performs *Simulation*. 2. For training, a device which duplicates the essential features of a task situation and provides for direct practice. 3. For *Distributed Interactive Simulation*, a *Physical Model* or *Simulation* of a weapons system, set of weapon systems or piece of equipment which represents some major aspects of the equipment's operation. |
| Supporter | Those who maintain or support simulations to the level of capability as accepted by the Simulation Manager from the Simulation Acquirer. This includes provision for technicians, logistics, people and data. This category also includes those who train others in simulation topics including how to build and run them. |
| Synthetic Environment | Internetted simulations that represent activities at a high level of realism from simulations of theatres of war to factories and manufacturing process. These environments may be created within a single computer or a vast distributed network connected by local and wide area networks and augmented by super-realistic special effects and accurate behavioural models. They allow visualisation of and immersion into the simulated. (USDOD Pub 5000.59-P, Army Model and Simulation Master Plan) |
| User | Those who use simulations, in an application area, and require more than a basic awareness of simulation to do this effectively. Those users who only require a basic understanding of simulation to use it, eg soldiers in a weapons simulation trainer, are not included in this category. |
| Validation | The formal process of determining the degree to which a *Model* or *Simulation* is an accurate representation of the *Real World* from the perspective of the intended uses of the *Model* or *Simulation*. |

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| Verification | 1. The formal process of determining that a *Model* implementation accurately represents the developer's conceptual description and specifications. 2. The formal process of determining whether a *Simulation Model* performs as intended. |
| Virtual Simulation | Virtual Simulations inject humans in the loop to exercise motor control, decision-making, or communications skills. The human element of a virtual Simulation is not modelled. The simulated systems in virtual Simulations would be made up of constructive Models. Examples include individual aircraft (or weapon system) simulators and virtual prototypes. |
| Wide Area Network | A communications network designed for large geographic areas |

# ANNEX C REFERENCE DOCUMENTS

1. The table details the reference documents relevant to this guide.

| *Serial* | *Reference* |
|---|---|
| A | Defence Instructions (General) OPS 42-1 – Defence Simulation Policy dated 3 October 2001. (Refer to ADSO website) |
| B | Defence Simulation Plan, Issue 1, dated 25 October 2002. (Refer to ADSO website) |
| C | IEEE Std 1278.1a-1998, IEEE Standard for Distributed Interactive Simulation - Application Protocols. |
| D | IEEE Std 1278.2-1995, IEEE Standard for Distributed Interactive Simulation – Communication Services and profiles. |
| E | IEEE Std 1278.3-1996, IEEE Recommended Practice for Distributed Interactive Simulation – Exercise Management and Feedback. |
| F | IEEE Std 1278.4-1997, IEEE Trial-Use Recommended Practice for Distributed Interactive Simulation – Verification, Validation, and Accreditation. |
| G | 'Enumeration and Bit Encoded Values for Use with Protocol's for Distributed Simulation Applications', www.sisostds.org. |
| H | IEEE Std 1516-2000, IEEE Standard for Modelling and Simulation (M&S) High Level Architecture (HLA) – Framework and Rules. |
| I | IEEE Std 1516.1-2000, IEEE Standard for Modelling and Simulation (M&S) High Level Architecture (HLA) – Federate Interface Specification. |
| J | IEEE Std 1516.2-2000, IEEE Standard for Modelling and Simulation (M&S) High Level Architecture (HLA) – Object Model Template (OMT) Specification. |
| K | IEEE Std 1516.3-2003, IEEE Recommended Practice for High Level Architecture (HLA) Federation Development and Execution Process (FEDEP). |
| L | SISO, 'Guidance, Rationale, and Interoperability Modalities for the Real-time Platform Reference Federation Object Model (RPR FOM)', Version 1.0, 10 September 1999. |
| M | Kuhl, F., Weatherly, R., Dahmann, J., 'Creating Computer Simulation Systems', Prentice Hall, 2000 |
| N | Zalcman, L., Ryan, P., Clark, P., Britton, M., 'JOANNE Standards for Training Simulator Interoperability', DSTO-TR-1462, July 2003. |
| O | Best, J, 'The Virtual Ship – A New Capability in Support of Maritime Forces', DSTO-GD-0198. January 1999. |
| P | Ryan, P., Clark, P., Rose, W., 'Evaluation of the DIS Test Suite', DSTO –CR-0232, February 2002. |
| Q | Ryan, P., Clark, P., Zalcman, L., 'Project JOANNE: Joint Air Navy Networking Environment', DSTO-TR-1300. July 2002. |
| R | Australian Defence Simulation Office, 'Defence Simulation Proposal Guide'. (Refer to ADSO website). |
| S | Ryan, P., Clark, P., Zalcman, L., 'Advanced Distributed Simulation for the Australian Defence Force', DSTO-GD-0255. October 2000. |
| T | Kazakevitch, E, 'DIS to HLA Migration Plan', DSTO. June 2002 |

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| U | NATO Report RTO-TR-050, 'NATO HLA Certification', June 2002. |
| V | SISO Paper REF-008-2002, Griffin et al, 'C4ISR/Sim Technical Reference Model Study Group Final Report (C4ISR/Sim TRM)' September 2002. |
| W | Simulation Interoperability Workshop Paper 03F-SIW-124, Carr et al, 'C4ISR/Sim Technical Reference Model Sourcebook'. |
| X | TTCP Report TR-JSA-2-1999, 'International Advanced Distributed Simulation Experiments', December 1999. |
| Y | TTCP Report TR-JSA-1-1999, 'Key Issues in Running International Advanced Distributed Simulation Experiments: Bandwidth, Latency, and Cost', December 1999. |
| Z | Clark, P., Ryan, P, Zalcman, L, Robbie, A, 'CReaMS PIE (Coalition Readiness Management Experiment) for Coalition Team Training Event', DSTO-TR-1361, October 2002. |

# ANNEX D PROTOCOL DATA UNIT SET EXAMPLES

317. The following table details the PDUs used by the FFG UP Project.

| PDU Name | Standard | | PDU | FFGUP Tx | FFGUP Rx |
|---|---|---|---|---|---|
| Standard PDUs | | * | | | |
| Entity State | IEEE 1278.1a 1998 | | 1 | Yes | Yes |
| Fire | IEEE 1278.1a 1998 | | 2 | *tbd* | No |
| Detonation | IEEE 1278.1a 1998 | | 3 | Yes | Yes |
| Collision | IEEE 1278.1a 1998 | | 4 | Yes | Yes |
| Service Request | IEEE 1278.1a 1998 | | 5 | No | No |
| Resupply Offer | IEEE 1278.1a 1998 | | 6 | No | No |
| Resupply Received | IEEE 1278.1a 1998 | | 7 | No | No |
| Resupply Cancel | IEEE 1278.1a 1998 | | 8 | No | No |
| Repair Complete | IEEE 1278.1a 1998 | | 9 | No | No |
| Repair Response | IEEE 1278.1a 1998 | | 10 | No | No |
| Create Entity | IEEE 1278.1a 1998 | | 11 | No | No |
| Remove Entity | IEEE 1278.1a 1998 | | 12 | No | No |
| Start/Resume | IEEE 1278.1a 1998 | | 13 | Optional | Optional |
| Stop/Freeze | IEEE 1278.1a 1998 | | 14 | Optional | Optional |
| Acknowledge | IEEE 1278.1a 1998 | | 15 | Optional | Optional |
| Action Request | IEEE 1278.1a 1998 | * | 16 | Optional | Optional |
| Action Response | IEEE 1278.1a 1998 | * | 17 | Optional | Optional |
| Data Query | IEEE 1278.1a 1998 | * | 18 | Local Use | Local Use |
| Set Data | IEEE 1278.1a 1998 | * | 19 | Local Use | Local Use |
| Data | IEEE 1278.1a 1998 | * | 20 | Local Use | Local Use |
| Event Report | IEEE 1278.1a 1998 | | 21 | No | No |
| Comment | IEEE 1278.1a 1998 | | 22 | Local Use | Local Use |
| Electromagnetic Emission | IEEE 1278.1a 1998 | | 23 | Yes | Yes |
| Designator | IEEE 1278.1a 1998 | | 24 | No | No |
| Transmitter | IEEE 1278.1a 1998 | | 25 | Yes | Yes |
| Signal | IEEE 1278.1a 1998 | | 26 | Yes | Yes |
| Receiver | IEEE 1278.1a 1998 | | 27 | Yes | Yes |
| IFF | IEEE 1278.1a 1998 | | 28 | Yes | Yes |
| Underwater Acoustic | IEEE 1278.1a 1998 | | 29 | Yes | Optional |
| Experimental PDUs | | | | | |
| Underwater Environment | DIS Experimental | | 220 | Yes | Yes |
| RAN FFGUP Chaff | DIS Experimental | | 221 | Yes | Yes |
| BFTT Surface Ship Systems Status (S4) | BFTT IDD Rev. 2 | * | 230 | Local Use | Local Use |
| BFTT Chaff | BFTT IDD Rev. 2 | | 231 | Yes | Yes |
| BFTT Environment | BFTT IDD Rev. 2 | * | 232 | Yes | Yes |
| BFTT Jammer | BFTT IDD Rev. 2 | | 233 | Yes | Yes |
| BFTT Supplemental Electromagnetic Emission (SEE) | BFTT IDD Rev. 2 | | 235 | Yes | Yes |
| RAN FFGUP Trainer Status | DIS Experimental | | 240 | Local Use | Local Use |
| RAN FFGUP Fused Track | DIS Experimental | | 241 | Local Use | Local Use |
| RAN FFGUP Electromagnetic Emission | DIS Experimental | | tbd | Yes | Yes |
| RAN FFGUP Link-11/Link-16 | DIS Experimental | | tbd | *tbd* | *tbd* |

# ANNEX E RUN TIME INFRASTRUCTURE PACKAGES

| Vendor | Compliance | Software bindings | DLC Compliant | Website | Other Details |
|---|---|---|---|---|---|
| **DMSO** | V1.3. | C++, Java, Ada, Corba IDL | No | http://ww.dmso.mil | No longer supported by DSMO but most widely used. DSTO has the source code and can be freely used within Defence. |
| **MäK** | IEEE 1516, V1.3 | C++ | Yes | http:www.mak.com | |
| **Pitch/Aegis** | IEEE 1516, V1.3 | C++, Java | Yes | http://www.pitch.se | |
| **VTC/SAIC** | V1.3 | C++, Java, Ada, Corba IDL | No | http://www.virtc.com | Based on DMSO product |
| **FDK** | ? | Limited C++ | ? | http://www.cc.gatech.edu/computing/pads/fdk.html | Used for building RTIs. Free for non-commercial use. |
| **yaRTI** | ? | Limited Ada bindings | ? | http://perso.wanadoo.fr/dominique.canazzi/dominique.htm | Written in French. Free download. |
| **Permian** | V1.3 | Java (C++ planned) | ? | http://permian.com.au | Limited functionality at this stage. |
| **Mitsubishi** | ? | ? | ? | ? | Written in Japanese |

ADSO recommends that an appropriate RTI is chosen in the first instance when developing HLA simulations. ADSO neither endorses nor recommends any of the products or vendors above. M&S projects should contact vendors directly to determine the suitability of commercial products for their specific applications. ADSO and DSTO will provide assistance as required.

**Distribution Simulation Guide**
**Evaluation Form**

Because this Guide will continue to be a 'living' document, ADSO welcomes your comments and will use the feedback to ensure that the Guide meets the needs of the audiences for which it is intended. Please take a moment to answer some or all of the five questions below. Including your name and address will be appreciated but is not necessary. Send your responses to:


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* * * * *

**1. According to your understanding of Distributed Simulation, is any information presented in this Guide incorrect or inaccurate? (You may want to attach a copy of the page marked with your suggested changes.)**

| *Page and line number* | *What is in error in this statement or discussion, in your estimation?* |
|---|---|
| | |
| | |

**2. In your opinion, should any discussions in the Guide be expanded and presented in greater detail? Is any statement or discussion unclear?**

| *Page and line number* | *What unanswered question(s) do you have after reading this material? For the work you do, what additional information do you need? Is this statement or discussion unclear?* |
|---|---|
| | |
| | |

**3. In your opinion, should any material in the Guide be eliminated or condensed?**

| *Page and line number* | *Why do you believe these statements or discussions should be omitted or shortened? (eg, 'too detailed for my needs,' 'redundant,' 'irrelevant for my needs,' 'too elementary.')* |
|---|---|
| | |
| | |

**4. Did you find any typos, misspellings, or other production errors in the Guide?**

| *Page and line number* | *Error* |
|---|---|
| | |
| | |

5. **Do you have any other suggestions for making the Guide a more effective and usable document?**

**Optional**

Name________________________________________________________________

Address______________________________________________________________

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Phone______________________________Fax___________________________________

e-mail address____________________________________________________________

***Thank you for taking the time to share your opinions with ADSO.***