



Australian Government
Department of Defence

Distributed Simulation Guide

Australian Defence Simulation Office

Department of Defence, Canberra

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Requests and inquiries should be directed to:

Director-General, Simulation
Australian Defence Simulation Office
Russell Offices [R1-3-B065]
Canberra ACT 2600
AUSTRALIA

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

The principle author, Darren Mc Farlane, would like to recognise the contributions made by the following Defence members. Your support is greatly appreciated.

Dr Peter Ryan	Stuart Marshall	LTCOL Craig Hersant	Dr John Best
Dr Richard Davis	Mark Fairleigh	LTCOL Mark Boyd	Dr John Wharington
George Rekkas	Dr Karyn Matthews	Maj Danial Munro	Dr Shane Canney
Dr Michael Davies	Dr Peter Clark	Lucien Zalcmán	Max Britton
Peter Ross	John Loughhead	WGCDR Grant Murphy	Rob Carpenter



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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:

Australian Defence Simulation Office
Russell Offices
R1-3-B065
CANBERRA ACT 2600

A handwritten signature in black ink that reads "Cliff White".

Cliff White
Director-General, Simulation
Australian Defence Simulation Office

Telephone: (02) 6265 2019
Facsimile: (02) 6265 2223
Email: cliff.white@defence.gov.au

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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 Policy¹ 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 strategy² 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.

¹ DI(G) OPS 42-1 Annex A Para 4.

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 Simulation³ 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. Distributed Simulation will take many independently constructed Simulations and provide the

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.

means to combine them together quickly and cheaply (physically or non-physically) to create a larger, more realistic Simulation (see Figure 2-2).

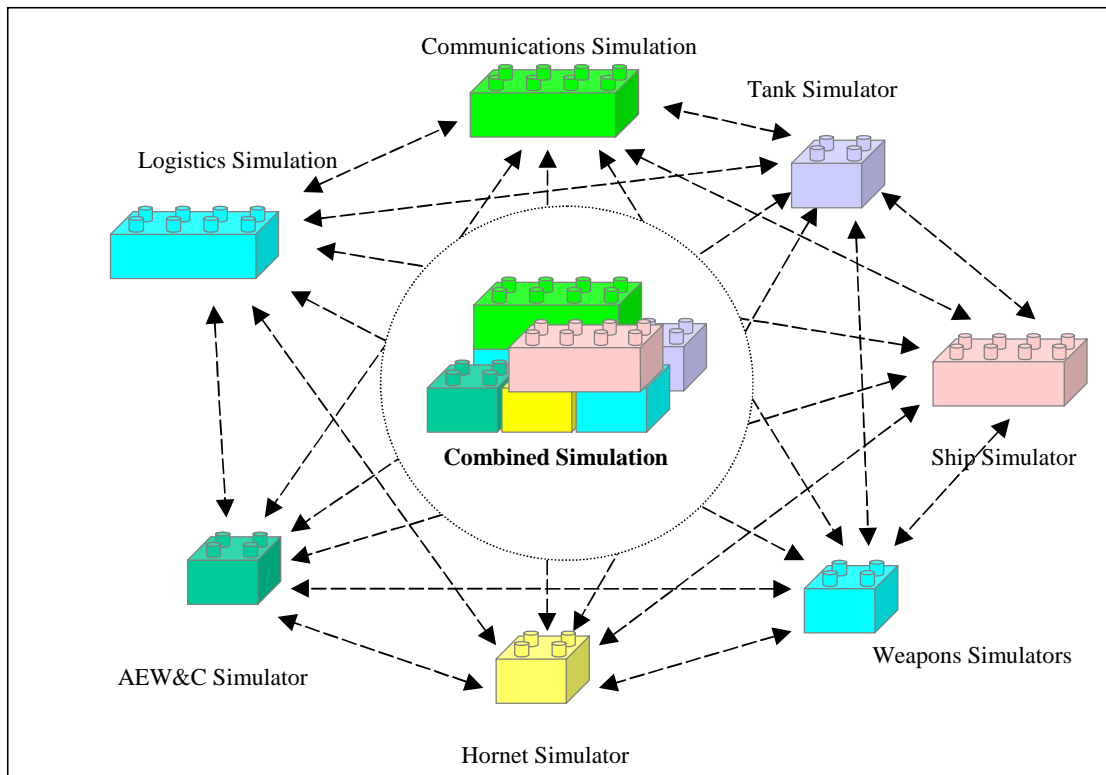


Figure 2-2: There is a need to combine many smaller Simulations into larger, adaptable Simulations to better represent the real world.

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.

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 program⁴ 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.

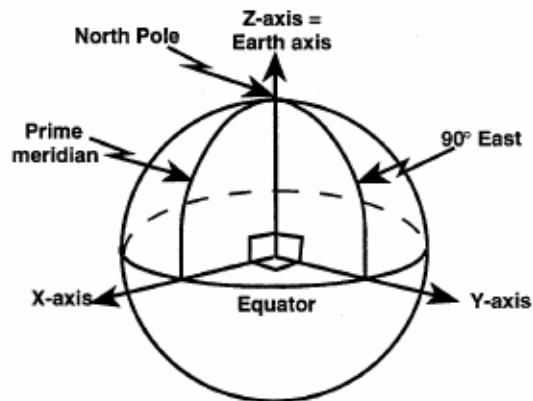


Figure 2-3: World Coordinate System⁵

11. Figure 2-4 shows a typical DIS interaction. The FFG detects the emissions of the aircraft and sends a Fire PDU. The missile is created via the Create Entity PDU and its trajectory is provided by information contained in the Entity State PDU. When the missile engages the aircraft a Detonation PDU is sent and a damage assessment is made.

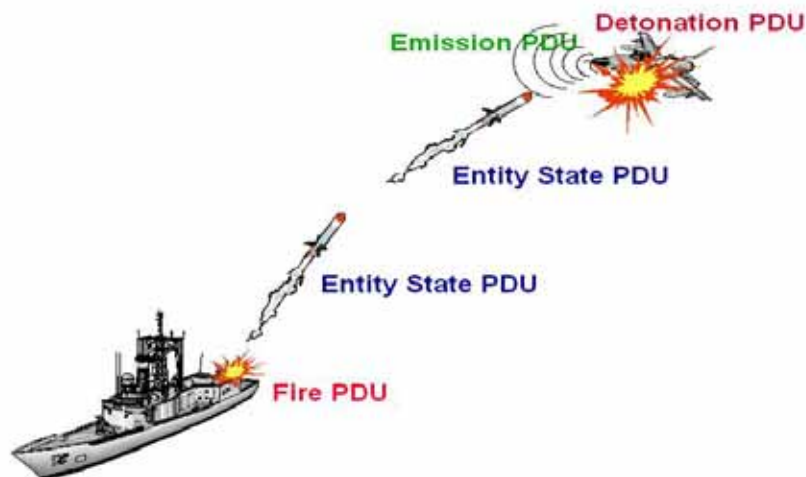


Figure 2-4: Diagrammatic representation of typical DIS interaction

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

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

<i>DIS version 1</i>	DIS PDU version 1.0 (May 1992)
<i>DIS version 2</i>	IEEE 1278 – 1993
<i>DIS version 3</i>	DIS 2.03 (3rd draft dated May 1993)
<i>DIS version 4</i>	DIS 2.04 (4 th draft dated March 1994)
<i>DIS version 5</i>	IEEE 1278.1 – 1995
<i>DIS version 6</i>	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

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 requirements⁶. 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 3. 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.

⁶ Refer to Annex E

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 PDU⁸

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

18. 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.

19. 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).

⁸ Source: Reference D

20. 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 8.1.

2.2.3 Advantages and disadvantages of distributed interactive simulation

21. 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.

22. 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

23. 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.dmsomil/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.

24. 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.
25. 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).

26. 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

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).

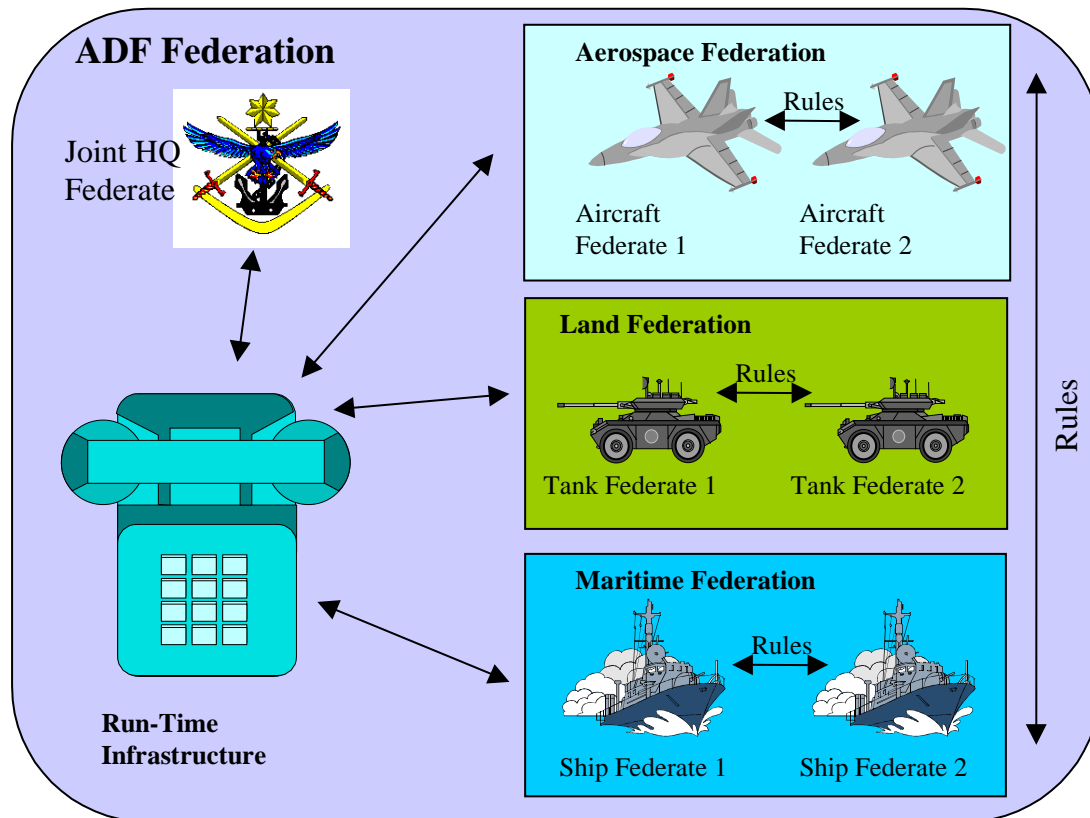


Figure 2-5: Representation of High Level Architecture software component Interactions

Note 4. An RTI can support more than one Federation at the one time.

27. 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.

28. 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

29. 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 standard is available for download from www.dmsomil.com.

30. 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.

31. 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 5. There is currently only one company that produces an IEEE 1516 compliant RTI (Pitch) and the cost of this RTI is relatively expensive. In the short term vendor lock in will be an issue for developers. However, other commercial products are expected to be compliant soon. 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.

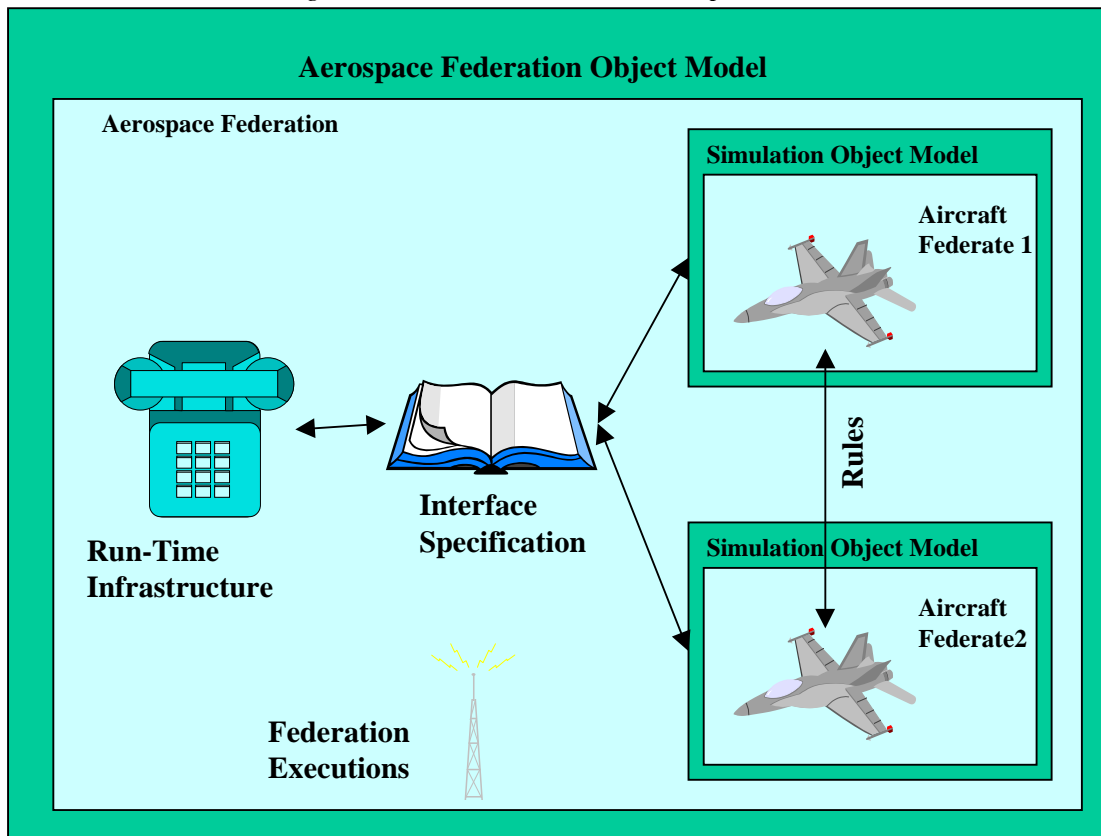


Figure 2-6: Representation of a typical HLA Standard Implementation

32. 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 6. 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 Infrastructure and support

33. HLA requires a RTI to interface with the Federate Simulation software. One version of the RTI is provided free by DMSO, although DMSO has stated that the product will not be further developed or sustained past 30 September 2002. Other versions are available on a commercial basis. DSTO should be consulted by Developers on the choice of RTI for particular applications.

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

35. A package called SIMplicity has been developed by Calytrix¹⁰, 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.

36. 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 8.2).

2.3.3 Advantages and disadvantages of the high level architecture

37. 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 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.

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

38. 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.

3 GUIDANCE FOR COMBINING SIMULATIONS

39. 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.

40. 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.

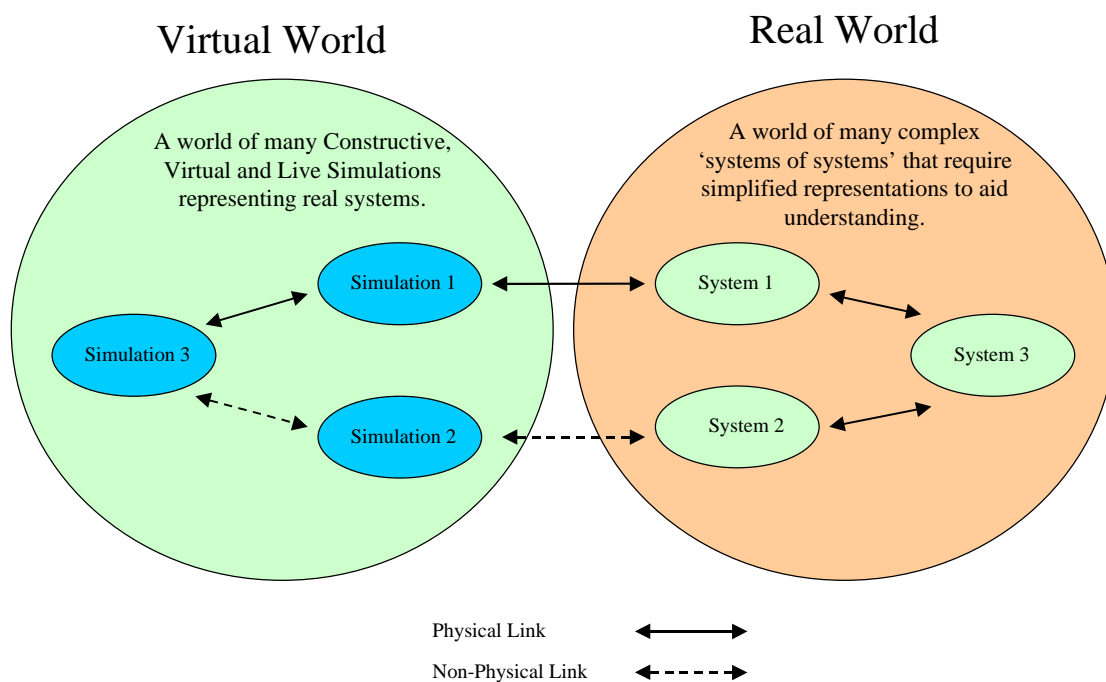


Figure 3-1: The combination of simulations can better meet real world needs

41. 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.

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

42. 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?

43. 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.

44. 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.

SPG is designed to help users understand and explain ...

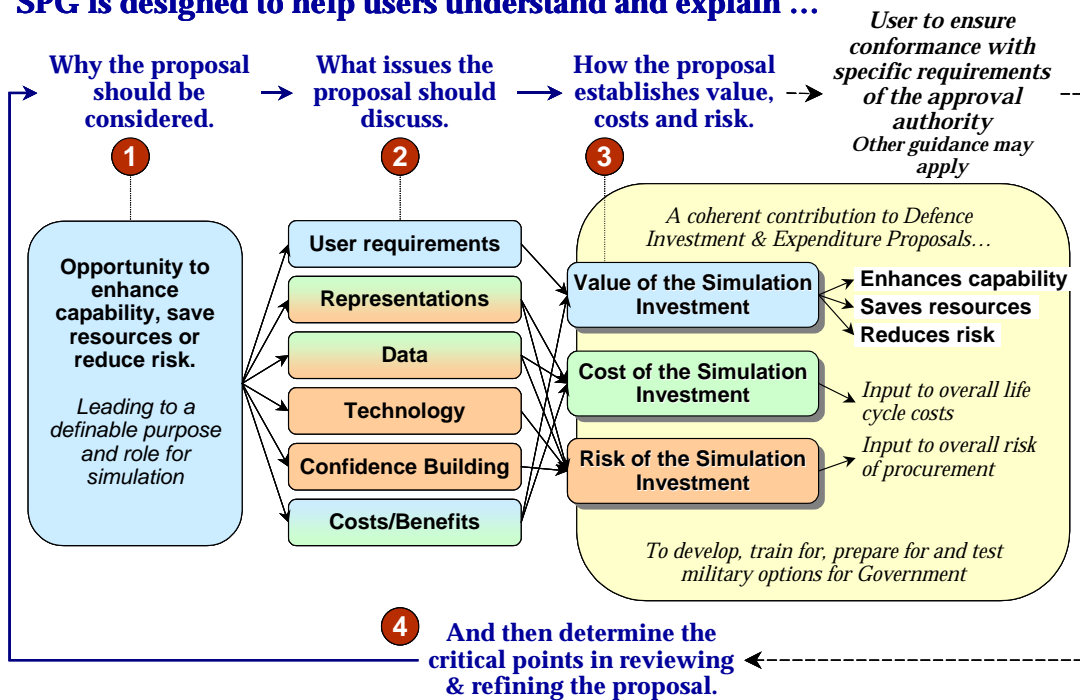


Figure 3-2: Concept for Simulation Proposal Guide

3.2 DESCRIBING THE INTERFACE

45. 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).

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

3.3 SAFETY CONSIDERATIONS

47. 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.

48. 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.

49. Safety will also need to be closely analysed and managed when ‘live’ and ‘virtual’ operations are being conducted at the same time.

3.4 COMMERCIAL SOFTWARE

50. 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 upgrades¹².
- 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

51. 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 products¹³:

¹² Source: Reference T.

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

52. 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

53. 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 7. It is recommended that the IEEE 1278.1a-1998 Standard PDUs be utilised for DIS Interoperability.

3.5.1.2 Protocol data unit interoperability

54. 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 8. 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

55. 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

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

<h2>3.6 COMBINING DISTRIBUTED INTERACTIVE SIMULATIONS TO HIGH LEVEL ARCHITECTURE SIMULATIONS</h2>

57. Migration of DIS to HLA is available via¹⁴:

- a. a gateway;
- b. middleware; or
- c. native HLA integration.

58. **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.

59. **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.

60. **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 reference federation object model

61. 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.

62. 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.

63. 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

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

Interoperability with other standard RPR FOM simulators and therefore making the reference FOM less useful.

64. 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 reference federation object model version 1.0

65. 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 reference federation object model version 2.0

66. RPR FOM 2.0, under development since 1999 and yet to be released, considerably extends RPR FOM 1.0. It will support DIS IEEE 1278.1a-1998 functionality including features such as environmental representation and underwater warfare.

67. Currently the RPR FOM 2.0 is at version 16, implying that it is nearing completion. It is expected that standardisation of the RPR FOM 2.0 will be complete early in 2004.

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

Note 9. As RPR FOM 2 is not yet complete, only future applications should cite the use of this standard.

3.6.2 Supporting tools

3.6.2.1 Commercial products

68. Some commercial gateway implementations are available and are more fully discussed at Reference T.

3.6.2.2 DSTOs distributed simulation infrastructure library interposer

69. 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.

70. 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.

71. **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.

72. **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).

73. **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?

74. 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.

75. 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.

76. 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.

77. 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 9.4.1).

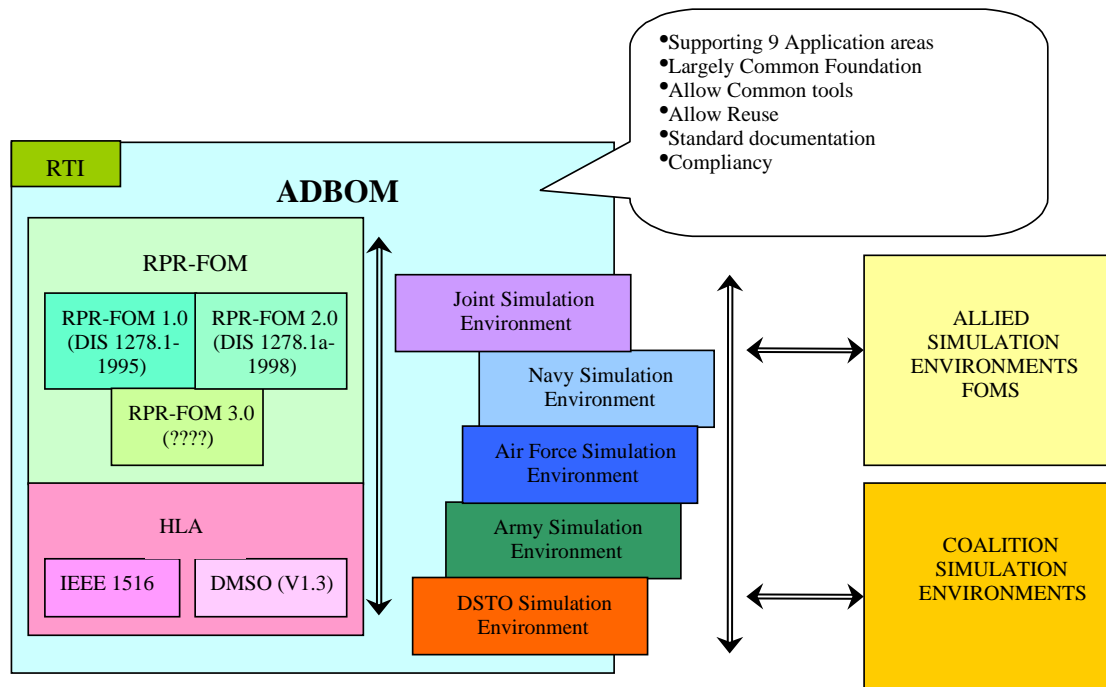


Figure 3-3: Current View of the Common ADBOM Framework

3.7.1.2 Australian Defence base object model guidelines

78. 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

79. Refer to Section 3.6.2.1.

3.7.2.2 SIMplicity

80. 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

81. 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

82. 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.

83. 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.

84. 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

85. The Defence Information Environment¹⁸ 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

¹⁵ ADFP 1, 30 Nov 93.

¹⁶ US Joint Pub 1-02 (as amended to 1 Sep 2000).

¹⁷ Source: Reference V.

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.

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.

86. 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

87. 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.

88. 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.

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

- a. STANAG 4482 for DIS;

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

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

91. 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.

92. To participate in future simulated coalition training exercises with the US Navy, it will be required that the ADF can interoperate with this FOM. This is currently being reviewed by DSTO.

4.4 SIMULATION/C4ISR SYSTEM INTEROPERABILITY

93. Many efforts²² 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

94. 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.

²¹ The NTMF working group website can be found at: <http://www.ntmf.com/>.

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.

²³ Source: Reference V.

4.4.1 The C4ISR/Simulation technical reference model

95. 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.

96. 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.

97. 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.

²⁴ Source: Reference V.

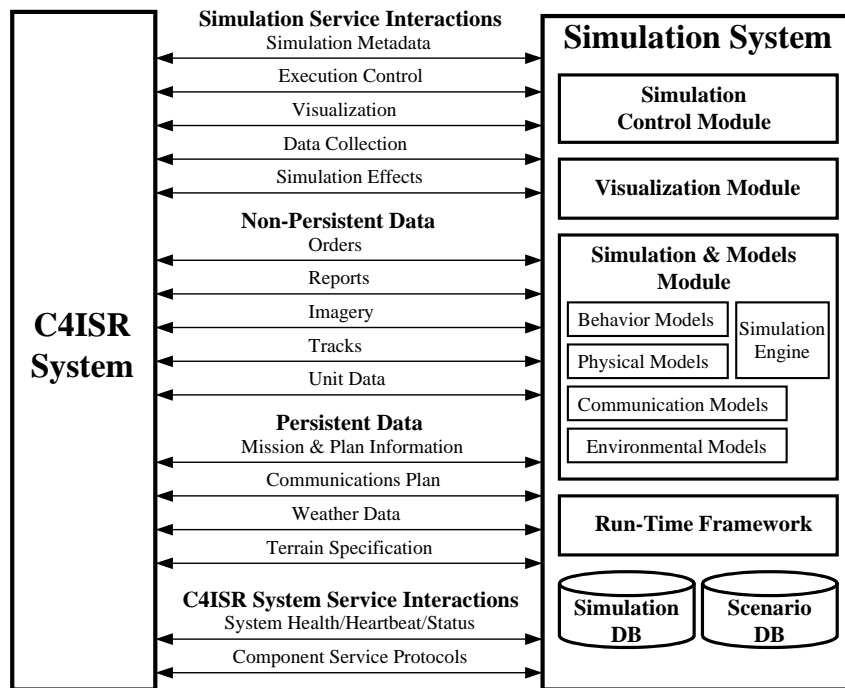


Figure 4-1: TRM Functional Interface Graphic

4.4.2 Voice Communications Interoperability

98. 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.

99. 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.

100. 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.

101. 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

102. 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.

103. 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.

104. 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.

105. 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

106. 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

107. 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

108. 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).

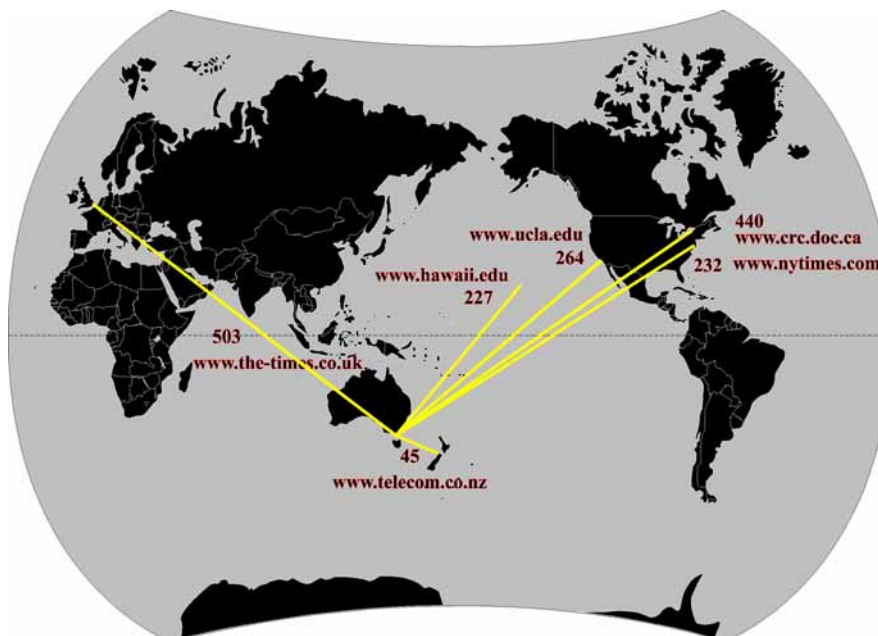


Figure 5-1: Measured minimum round trip Internet Latencies (in msec) from Melbourne

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

²⁶ Source: Reference X.

109. 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

110. 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

111. 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.

5.2 EXISTING AND FUTURE AUSTRALIAN NETWORKS

5.2.1 Integrated services digital network services

112. 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

113. 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

114. 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.

115. 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.

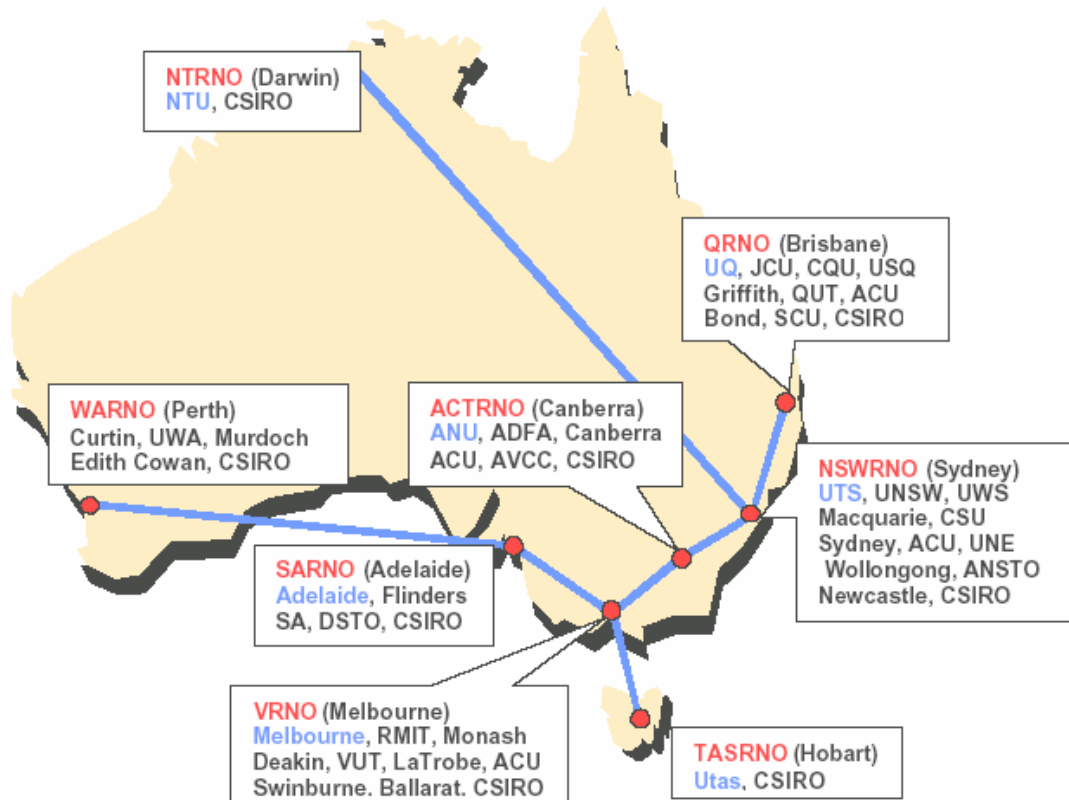


Figure 5-2: AARNET Australian Backbone Network

5.2.4 JP 2047 – Defence wide area communications network

116. 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

117. 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

118. 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

119. Refer to Sections 5.2.1 and 5.2.2.

5.3.2 Australian academic and research network

120. 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.

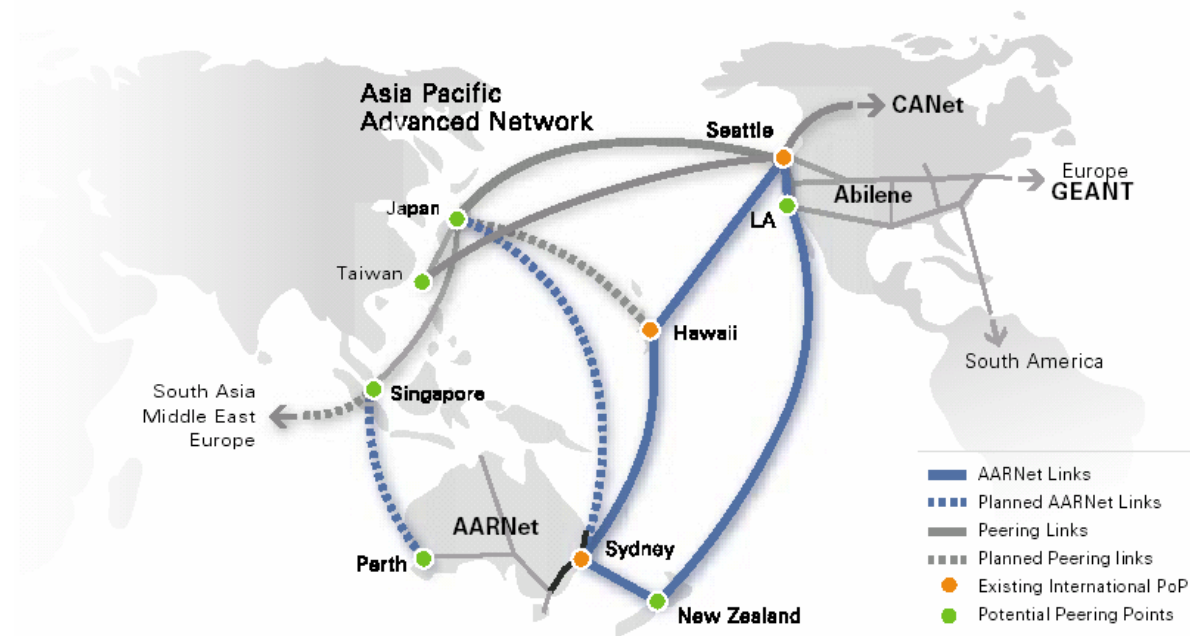


Figure 5-3: AARNET International Backbone Network

5.3.3 Combined federated battle labs

121. 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

122. 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

123. 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.

124. The basic Architecture concepts of DIS are²⁷:

- 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

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.

125. 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.

126. 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

127. 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	

128. 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.

129. 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

130. 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.

131. 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

132. 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

133. 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

134. 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

135. 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.

136. 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

137. 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

138. 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

139. 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

140. 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

141. 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

142. 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

143. 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

144. 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

145. 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

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

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

6.2 SUPPORTING TOOLS

147. 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

148. 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

149. 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

150. 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 8.1.2);

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

151. A functional view of HLA is shown in Figure 7-1³⁰. 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.

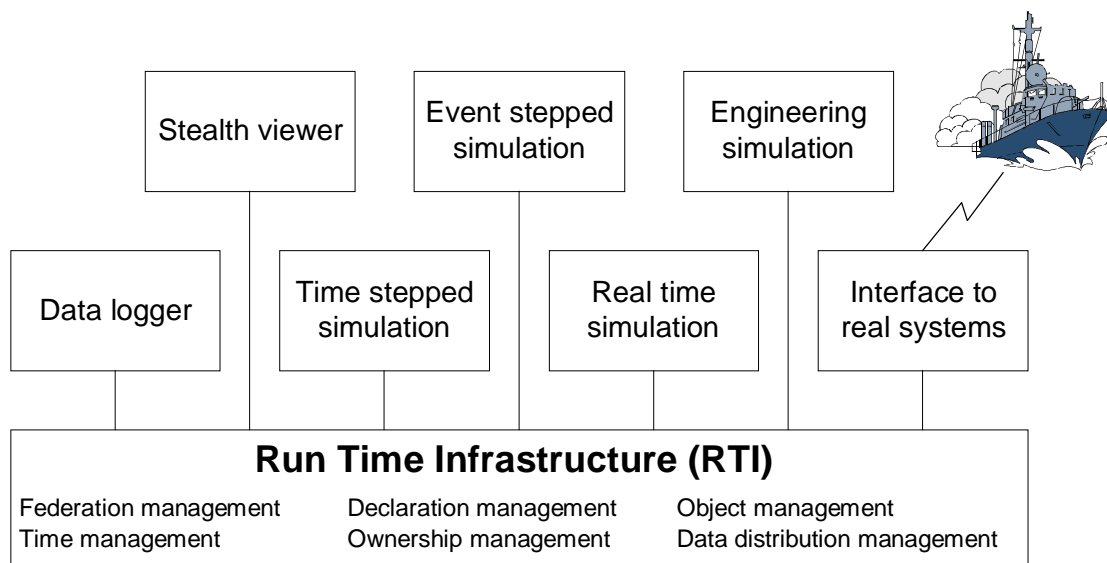


Figure 7-1: Functional View of HLA

152. 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.

³⁰ Source: Reference O.

7.1.2 Summary of the high level architecture rules

153. The rules for Federations are as follows³¹:
- 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.
154. 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.
155. Further detail on the HLA rules can be found in Reference H.

7.1.3 The high level architecture object model template

156. 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).

157. 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.

³¹ Source: Reference H.

158. 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.

159. 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

160. 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).

161. 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

162. 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.

163. 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

164. 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

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

166. 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.

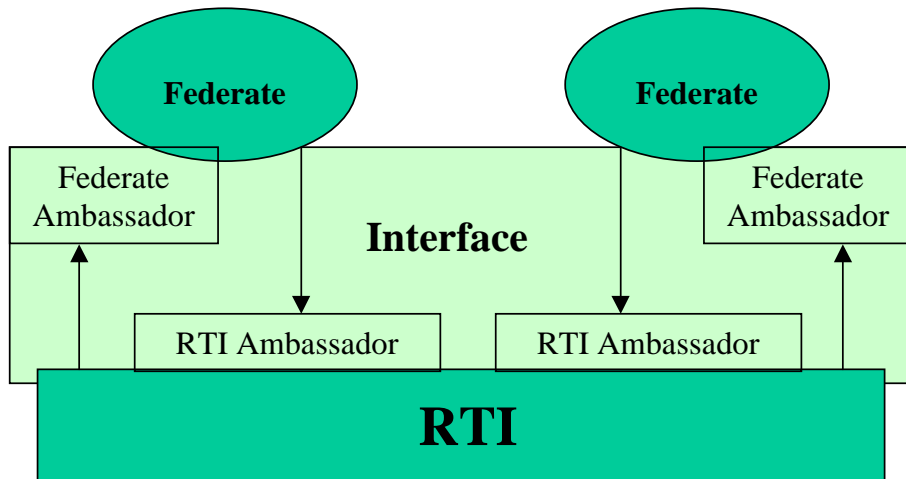


Figure 7-2: Interfaces between RTI and Federates³³

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

7.1.4.1 The run time infrastructure

168. 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.

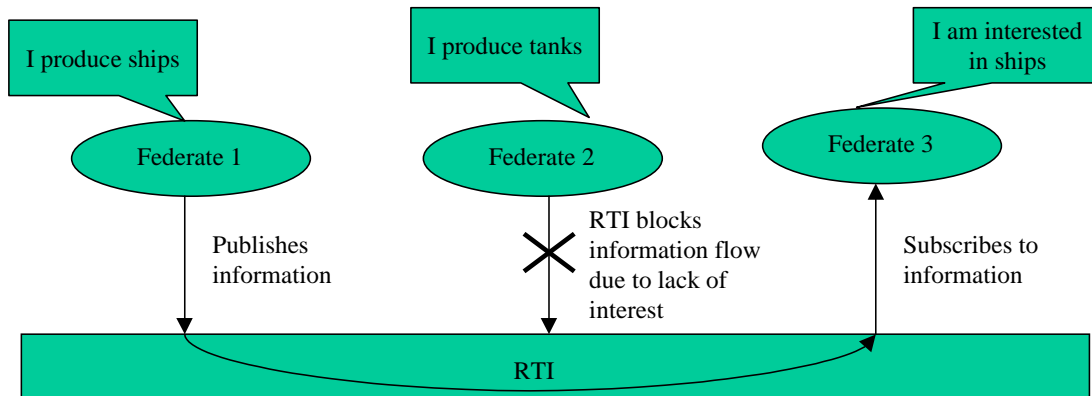


Figure 7-3: HLA Publication and Subscription

169. 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.

³² Source: Reference O.

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.

170. The choice as to which RTI to use in a Federation is very important. There are several types of RTI on the market, all with different advantages and disadvantages (see Annex). For example the MAK RTI adds 4 bytes of overhead per attribute/parameter, while the DMSO RTI adds 8. The DMSO RTI is a free RTI (available from DSTO) and the MAK RTI needs a license per execution. Additionally, the RTI implementations use differing software languages.

171. 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.

7.1.5 The federation development and execution process

172. 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.

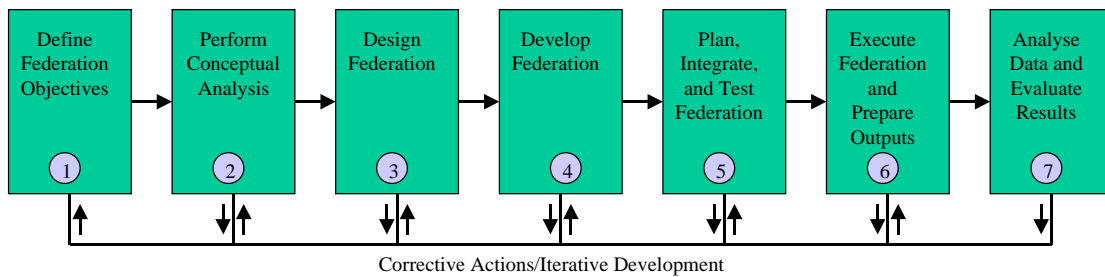


Figure 7-4: FEDEP, top-level view³⁴

173. 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.
- 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.

³⁴ Source: Reference K.

7.1.6 Further technical information

174. 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.dmsomil/public/>.

7.2 SUPPORTING TOOLS

7.2.1 High level architecture development tools

7.2.1.1 SIMplicity

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

176. 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.

177. 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

178. 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.dmsomil/public/> (ie Object Model Development Tool, Object Model Library and Object Model Data Dictionary) and commercial vendors.

7.2.1.3 Planning federation execution

179. 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.dmsomil/public/>.

7.2.2 Viewers and dataloggers

180. See Section 6.2.

8 VERIFICATION, VALIDATION & ACCREDITATION OF DISTRIBUTED SIMULATIONS

181. 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.dmsso.mil/public/transition/vva).

182. 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.

183. 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.

8.1 DISTRIBUTED INTERACTIVE SIMULATION VERIFICATION, VALIDATION AND ACCREDITATION

184. 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.

185. 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.

8.1.1 Distributed interactive simulation test suite

186. 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.

8.1.2 Distributed interactive simulation protocol data unit generator

187. 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.

8.2 HIGH LEVEL ARCHITECTURE VERIFICATION, VALIDATION AND ACCREDITATION

188. 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.

189. 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.

Note 17. 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.

190. 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.

8.2.1 The current US certification process

191. 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@dmsomil.

192. 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.

8.2.2 High level architecture certification issues

8.2.2.1 Security

193. 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.

194. 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.

8.2.2.2 Defence modeling simulation office certification

195. 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 DISTRIBUTED SIMULATION SUPPORT

9.1 TRAINING AND EDUCATION

9.1.1 High level architecture training

9.1.1.1 University of Ballarat

196. 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.

9.1.1.2 Permian

197. 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.

9.1.2 Distributed interactive simulation training

198. 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.

9.2 SUBJECT MATTER EXPERTS

199. 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).

9.2.1 Defence Science and Technology Organisation

9.2.1.1 Air Operations Division

200. The Advanced Distributed Simulation Laboratory within AOD continues to build expertise in Distributed Simulation while advancing the JOANNE Project (see Section 9.3.6). They also develop Distributed Simulation applications and can provide advice on a wide range of COTS Distributed Simulation tools.

9.2.1.2 Maritime Operations Division

201. The Maritime Operations Division operates the Virtual Ship and Virtual Submarine (see Section 9.3.4) and has accumulated an expertise in building HLA based Simulations.

9.2.1.3 Maritime Platform Division

202. 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.

9.2.1.4 Command and Control Division

203. 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 9.4.2).

9.2.1.5 Land Operations Division

204. Land Operations Division operates the SERF (see Section 9.3.5) which uses DIS Virtual Simulation. LOD staff also employs One SAF and JSAF.

9.2.2 Army

9.2.2.1 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 9.3.1) which is based on HLA. Points of contact are:

9.2.3 Navy

9.2.3.1 HMAS WATSON

205. 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 9.3.3). They have links to the US BFTT program through the CREAMS project.

9.2.4 Defence Material Organisation

9.2.4.1 Maritime Systems Division

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

9.2.4.2 Aerospace Systems Division

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

9.2.4.3 Land Systems Division

208. Land Systems Division provides Simulations for Army.

9.2.5 Office of the Chief Information Office

9.2.5.1 Australian Defence Simulation Office

209. 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.

<h2>9.3 PROJECTS CURRENTLY USING DISTRIBUTED SIMULATION</h2>

9.3.1 Army synthetic environment

210. 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.

9.3.2 Virtual air environment

211. 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.

212. 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.

213. 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.

214. 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.

215. 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 9-1.

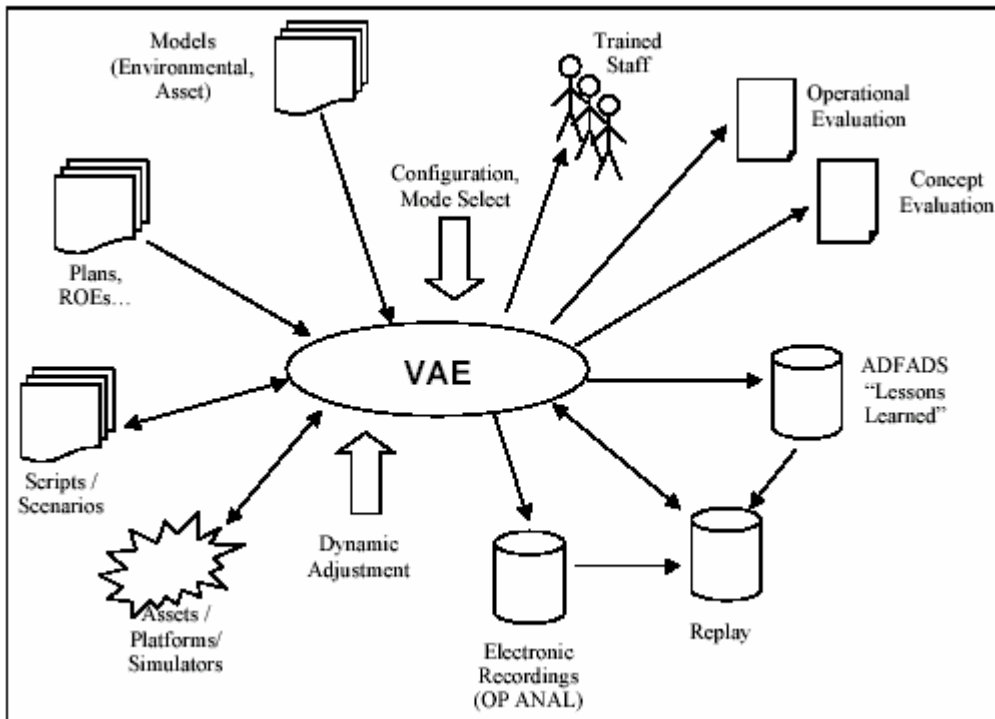


Figure 9-1: VAE Capability Overview**9.3.3 Maritime warfare training system**

216. 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.

217. 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.

218. 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.

219. 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.

220. 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 9-2 below.

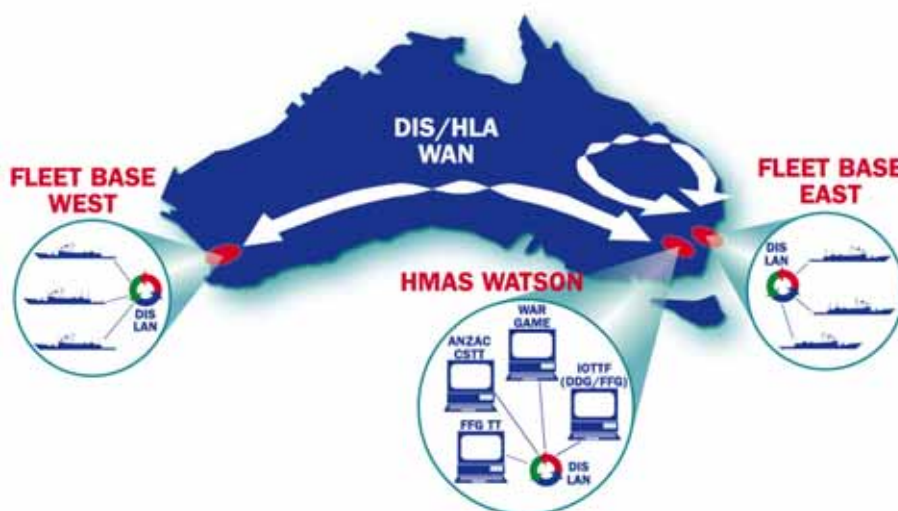


Figure 9-2: MWTS Wide Area Network

221. 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).

222. 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.

223. 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.

9.3.4 Virtual maritime system

224. 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.

9.3.5 Synthetic environment research facility

225. 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.

226. 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.

9.3.6 DSTO's JOANNE project

227. 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.

228. 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 9.3.3), 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 9.3.4).

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

9.3.6.1 JOANNE research issues

230. 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.

9.3.6.2 International collaboration: RAN/USN/DSTO

231. 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).

9.3.6.3 Advanced distributed simulation laboratory

232. 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.

9.4 PROJECTS PLANNING TO USE DISTRIBUTED SIMULATION

9.4.1 Joint simulation capability

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

234. 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.

235. To create this adaptive capability, the JSC requires five dimensions to co-exist (see Figure 9-3):

- 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.

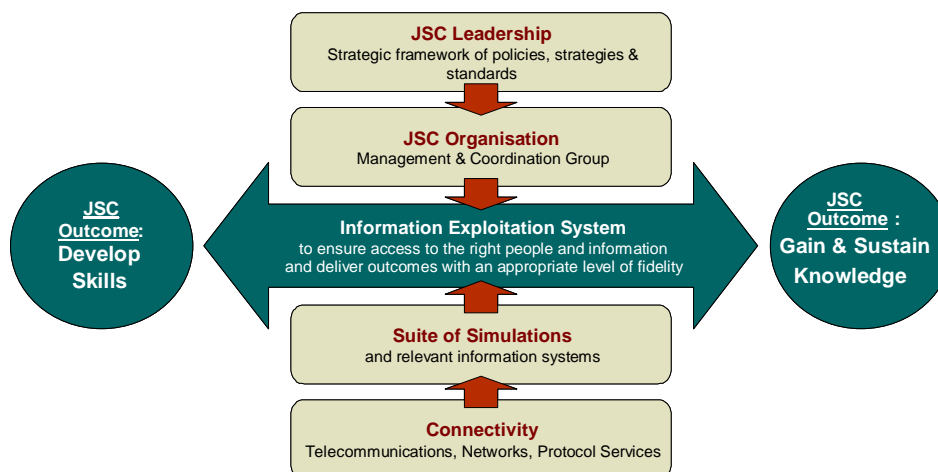


Figure 9-3: Five co-existing dimensions are required to deliver the JSC outcomes

9.4.1.1 Performance objectives

236. 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.

9.4.1.2 Initial Joint simulation capability

237. 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.
238. 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 9-4.

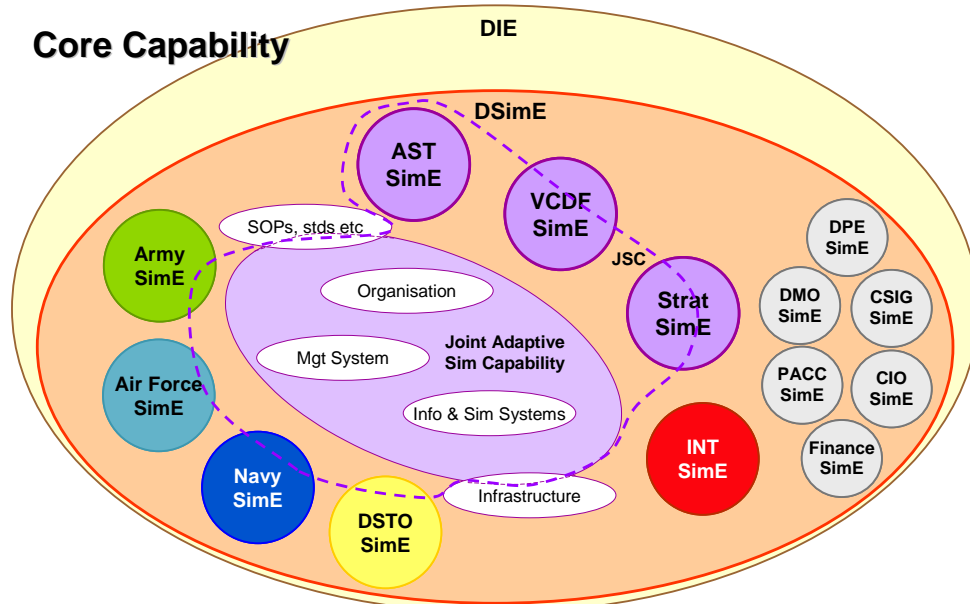


Figure 9-4: Illustrative Initial Boundary of the JSC

239. 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.

9.4.2 Course of action simulation

240. 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.

241. 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 9-5.

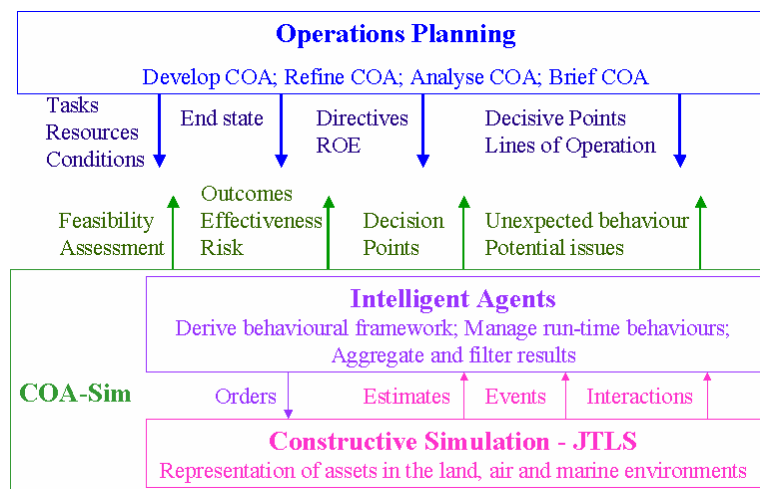


Figure 9-5: Example roles of Simulation in support of planning.

242. COA-Sim enables:

- Computer tracking of a COA (the time and space motion of assets) and allows for back-tracking or fast-forwarding,
- Exploration of the feasibility, effectiveness and risk of a single task through to an entire COA,
- Exploration of logistics feasibility,
- Wargame adjudication – provides representative outcomes,
- Exploration of task synchronisation issues, and
- Determination of decision points.

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

244. 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 9-6.

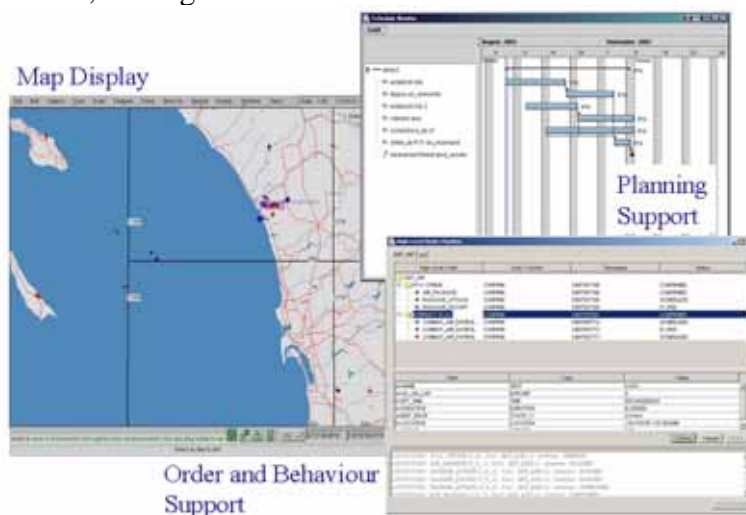


Figure 9-6: Example COA-Sim environment interface.

245. 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

- 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
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	Communication and Information Systems
COA-SIM	Course Of Action – Simulation
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
FOM	Federation Object Model
HLA	High Level Architecture
IEEE	Institute of Electrical and Electronics Engineers
ISDN	Integrated Services Digital Network
JOANNE	Joint Air Navy Networking Environment Project
JSAF	Joint Semi Automated Forces
JSE	Joint Synthetic Environment

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JTLS	Joint Theatre Level Simulation
JWID	Joint Warfare Interoperability Demonstration
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
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
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 <i>Synthetic Environment</i> is created through <i>Real Time</i> exchange of IEEE 1278 compliant <i>Protocol Data Units</i> between distributed, computationally autonomous <i>Simulation</i> applications in the form of

	<i>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.</i>
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 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).
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

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.

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: a. simulation entities, terrain, atmospheric, bathyspheric and cultural information; and all the conditions, circumstances; and 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 <i>Simulation</i> . 2. For training, a device which duplicates the essential features of a task situation and provides for direct practice. 3. For <i>Distributed Interactive Simulation</i> , a <i>Physical Model</i> or <i>Simulation</i> 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	Internetworked 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 <i>Model</i> or <i>Simulation</i> is an accurate representation of the <i>Real World</i> from the perspective of the intended uses of the <i>Model</i> or <i>Simulation</i> .

Verification	1. The formal process of determining that a <i>Model</i> implementation accurately represents the developer's conceptual description and specifications. 2. The formal process of determining whether a <i>Simulation Model</i> 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.

<i>Serial</i>	<i>Reference</i>
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, Zalzman, 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

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

PDU Name	Standard	PDU	FFGUP Tx	FFGUP Rx
<u>Standard PDUs</u>				
Entity State	IEEE 1278.1a 1998	1	Yes	Yes
Fire	IEEE 1278.1a 1998	2	<i>tbd</i>	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
<u>Experimental PDUs</u>				
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	<i>tbd</i>	<i>tbd</i>

ANNEX E RUN TIME INFRASTRUCTURE PACKAGES

Vendor	Compliance	Software bindings	Website	Other Details
DMSO	V1.3.	C++, Java, Ada, Corba IDL	http://ww.dmsomil	No longer supported by DSMO but most widely used. DSTO has the source code and can be freely used within Defence.
Mäk	V1.3	C++	http://www.mak.com	
Pitch/Aegis	IEEE 1516, V1.3	C++, Java	http://www.pitch.se	
VTC/SAIC	V1.3	C++, Java, Ada, Corba IDL	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:

Mr Darren Mc Farlane
 ADSO Navy 1
 R1-3-B037a
 Phone: (02) 6265-4797; Fax: (02) 6265-2223;
 e-mail: darrenmcfarlane@defence.gov.au

* * * * *

- 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.)**

<i>Page and line number</i>	<i>What is in error in this statement or discussion, in your estimation?</i>

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

<i>Page and line number</i>	<i>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?</i>

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

<i>Page and line number</i>	<i>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.')</i>

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

<i>Page and line number</i>	<i>Error</i>

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

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