Interoperable Aerospace Training Simulators within the Australian Defence Force

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Abstract. Within the Australian Defence Force, Army, Navy, and Air Force are separately taking delivery of sophisticated aerospace training simulators to provide aircrew training for new platforms such as the Armed Reconnaissance Helicopter (ARH), the Super Seasprite helicopter, and the Airborne Early Warning and Control (AEW&C) and F/A-18 aircraft. At the same time, Air Force is developing its Aerospace Battlelab Capability (ABC), Navy is developing its Maritime Warfare Training System (MWTS), and Army its Army Synthetic Capability (ASC) that will utilise these simulators in various roles including training, doctrine and tactics development. To maximise their potential it is essential that these training simulators be able to interoperate amongst each other using standard distributed simulation protocols. This must include exchange of simulated entity, data link, and communications information so that the various synthetic platforms can fully interoperate in a synthetic battlespace like real military assets in a real battlespace. DSTO has been working with the Defence Materiel Organisation (DMO) and assisting both Air Force and Navy with simulator interoperability issues including advising the project offices, testing systems in the field, and reporting where there are existing or potential future deficiencies such as inadequate provision for handling externally generated synthetic entities. This paper provides a status report on the potentially interoperable aerospace training simulators, and reviews the standards, policies, and procedures needed to make a truly networked synthetic ADF that is also able to interoperate with coalition partners.

1. INTRODUCTION

It is the year 2020: the ADF has deployed its forces and is carrying out an expeditionary operation in support of a friendly Pacific nation, as shown in Figure 1. Joint Strike Fighter (JSF) Aircraft are flying Combat Air Patrol (CAP) whilst receiving data link feeds from a Wedgetail Airborne Early Warning & Control (AEW&C) aircraft and an Air Warfare Destroyer (AWD) stationed off coast, HMAS Sydney V. The AWD is escorting several amphibious craft. An A330 Tanker aircraft is moving into the area of operations to refuel both the AEW&C and the two JSF aircraft. A Multi-mission Maritime P-8 Aircraft (MMA) is providing long range reconnaissance assisted by Global Hawk aircraft flying undetected at high altitudes.

However, although real crews are engaged, no real aircraft are flying. The entire scenario is taking place in a synthetic environment using the ADF's suite of advanced training simulators. These systems replicate the real systems, providing the look, feel and response of the real aircraft. Further, they can be linked together to provide a joint synthetic training environment for training crews in mission rehearsals and tactics evaluation.

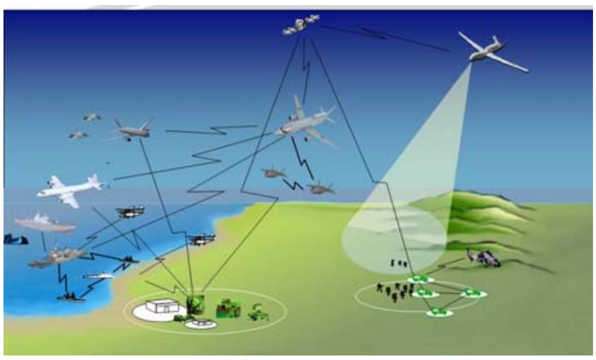

Figure 1: Future Network Centric ADF Operation

Is this science fiction? No, as this paper will show, the ADF is developing a suite of sophisticated training simulators that can provide such combined and joint operational training for ADF crews within the next 10 years.

2. ADF AEROSPACE TRANSFORMATION

Across the next 10 years, the ADF will introduce aircraft into service with complex integrated systems for sensing, electronic protection, weapons delivery and networking, leading to networked operational capability. Some $A30 billion is being invested in new and upgraded aerospace platforms and capabilities. In chronological order, these aircraft comprise the Armed Reconnaissance Helicopter (ARH), the Airborne Early Warning and Control Aircraft (AEW&C), the Multi-Role Hornet Upgrade Aircraft, the Navy's Seasprite Surface Surveillance and Response Helicopter, the Air to Air Refueller, the Unmanned High Altitude Long Endurance (HALE) Unmanned Aircraft, the Medium Lift Helicopter, the Joint Strike Fighter, the Multi-Mission Maritime Aircraft, and the Sea Hawk Multi-Mission Helicopter. Additional Troop Lift Helicopters are also being acquired by Army. More recently, the ADF has decided to purchase C-17 Globemaster Heavy AirLift (HAL) aircraft.

Within the ADF, Army, Navy, and Air Force are separately acquiring sophisticated aerospace training simulators to provide aircrew training for these new and existing platforms. To maximise their potential, it is essential that these training simulators be able to interoperate among each other using standard distributed simulation protocols.

DSTO has been working with Defence Materiel Organisation (DMO) and assisting both Air Force and Navy with simulator interoperability issues including advising the project offices, testing systems in the field, and reporting where there are existing or potential future deficiencies such as inadequate provision for handling externally generated synthetic entities. These testing procedures were discussed at a previous SimTecT Conference [1].

This paper provides a status report on the potentially interoperable aerospace training simulators and reviews the standards, policies, and procedures needed to make a truly networked synthetic ADF that is also able to interoperate with coalition partners.

3. ADVANCED DISTRIBUTED SIMULATION

Advanced Distributed Simulation (ADS) was created to link simulators, simulations and/or real devices so that the various entities can interact with each other to conduct a simulated game or exercise in the same synthetic battlespace. The simulation nodes may be collocated or may be geographically remote from each other.

ADS has been under development since the early 1980s with the Simulator Networking (SIMNET) Project undertaken by the US Defense Advanced Research Projects Agency [2]. SIMNET was transitioned to the US Army and is still in service for training tank crews. ADS development continued through the emergence of Distributed Interactive Simulation (DIS) [3] in the early 1990s and High Level Architecture (HLA) [4] in the late 1990s. In parallel with these efforts, the Test and Training Enabling Architecture (TENA) has been established to enable the live range community to participate in distributed simulation exercises [5].

Air Operations Division of DSTO has been closely associated with advanced distributed simulation exercises for over a decade. In that time, considerable experience has been gained with establishing interoperability among simulations and simulators, and also with testing fielded systems. AOD has also established formal involvement with international standards activities through the Simulation Interoperability Standards Organisation (SISO) [6] and Standards Australia [7].

4. ADF AEROSPACE SIMULATORS

Existing Australian network-enabled training simulation systems include the Royal Australian Navy's (RAN) Maritime Warfare Training Centre (MWTC) simulators and the Royal Australian Air Force's (RAAF) AP-3C training simulators. Naval On Board Training Systems being acquired for the FFG class can also be networked for enhanced training opportunities. Details of these systems can be found on the Defence Materiel Organisation (DMO) web site [8].

In previous work, DSTO has assisted Navy with ensuring that their main surface warfare simulators are interoperable. These systems have also been connected externally to USN systems for enhanced training under the Coalition Readiness Management System Project Arrangement (CReaMS) [9].

4.1 Air Force Systems

The RAAF has several existing networkable simulators and several other potential ones. These potential networkable systems are described in the next subsections.

4.1.1 AP-3C

The AP-3C under Project AIR 5376 has two new simulators, the Advanced Flight Simulator (AFS) and the Operational Mission Simulator (OMS). The AFS provides a 'front end' simulation of the AP-3C from the pilot's perspective whereas the OMS provides a 'back end' simulation of the aircraft.

Both of these systems have been equipped with DIS interfaces to provide interoperability and these interfaces have been tested by DSTO. However, some issues have been noted with these interfaces. A common problem is the restricted number of entities that each system can handle. It is envisaged that an

ADF networked simulator should be able to handle several hundred virtual entities.

4.1.2 AEW&C

The AEW&C will have two network-enabled simulators similar to the AP-3C, an Operational Flight Trainer (OFT) that provides flight training, and an Operational Mission Simulator (OMS) that provides back end mission training. These systems will have DIS interfaces to enable interoperability with other systems.

4.1.3 Hornet Upgrade Aircraft

The DMO is upgrading the RAAF's F/A-18 Hornet fleet of fighter aircraft with new systems including enhanced avionics, radar, and electronic warfare capability. At the same time, new simulators are being acquired to provide training for the upgraded aircraft. These Hornet Aircraft Crew Training Systems (HACTS) will be delivered with HLA interfaces enabling them to be networked among themselves. The HLA interface will use the Naval Training Meta Federation Object Model, developed by the US Navy.

4.1.4 Other Aerospace Simulators

The current transport aircraft (C-130J and C-130H) simulators are being equipped with DIS interfaces. These will then be able to be linked together in a Local Area Network at RAAF Richmond for combined training exercises and will also be able to be connected into wider simulation networks and exercises.

In the future, the RAAF will also acquire new aircraft including:

- Joint Strike Fighters (in the 2012 – 2018 timeframe) provided from the New Air Combat Capability (NACC) Project
- Unmanned Aerial Vehicles provided as part of AIR 7000
- Replacement aircraft for the AP-3C (possibly the USN's P-8A - Multi-mission Maritime Aircraft (MMA) provided by AIR 7000). These are not expected to be delivered before 2015.
- Air-to-Air refuelling aircraft being delivered under Project Air 5402. These will have a Full Flight Simulator to be provided as part of prime contract. Its interoperability is not yet fully defined, but is expected to be HLA.

Simulators will be included with these acquisitions as part of comprehensive training packages.

4.2 Navy Aerospace Systems

The RAN has developed a program to link up present and future training systems into a Maritime Warfare Training System (MWTS) as shown in Figure 2. This system will be expanded to include ships based alongside and in the future at sea and also Navy and RAAF aerospace simulators to provide enhanced training opportunities.

Figure 2: Anticipated development of Navy's Maritime Warfare Training System

Navy's main operational aircraft are the Seahawk, Sea King and Seasprite helicopters. Of these, the Seasprite simulator has a DIS interface. DSTO will assist Navy with testing this simulator and its interoperability during 2007. Further Navy training systems may be acquired under Project AIR 9000 [8].

4.3 Army Aerospace Systems

Army operates the Blackhawk and shortly, the Armed Reconnaissance Helicopter (ARH). The ARH will be equipped with a range of training systems including full flight and mission simulators for both the pilot and battle captain and crew procedural trainers. The aircrew training devices will be located at different Army training establishments and are planned to be networked using DIS.

Army will also take delivery of MRH90 helicopters as part of the AIR 9000 Project. These will likely come with training simulators as part of the purchase that may also include the capability of being networked into a wider training environment with the Army Synthetic Environment [11].

4.4 Summary: ADF Aerospace Simulators

Figure 3 provides an estimated time line for development of the ADF's aerospace simulators across the three services.

Figure 3: Timeline for development of the ADF's aerospace simulators

Whilst the RAAF systems predominate, there are still significant aerospace simulation assets within both Navy and Army such as the ARH and Seasprite. The Sea Hawk is included here for completeness but its training simulator does not have network capability.

5. TECHNICAL REQUIREMENTS FOR SIMULATORS

To effectively interoperate and achieve a common synthetic environment among several systems, the following areas need to be considered:

- Advanced Distributed Simulation
- Voice Communications
- Data Link
- Simulator Capability and Fidelity
- Networking infrastructure
- Encryption

The first three of these areas are discussed in detail in [12].

5.1 Advanced Distributed Simulation

Training simulation systems are generally specified with either DIS or HLA interfaces. While either system can be used to connect simulators, it needs to be appreciated that these techniques have fundamental differences.

DIS is a networking protocol standard that uses standardised Protocol Data Units (PDUs) for exchanging data across the network. The PDU structures, data handling algorithms (such as dead reckoning) and data stored in those structures standardised by IEEE ([13], [14], [15]), ensure a high degree of "out-the-box" interoperability for DIS compliant devices.

In contrast, HLA is a methodology designed to support distributed simulation exercises. HLA originated to provide flexibility to develop, reuse, and connect federates into groups (federations) to satisfy a diverse set of requirements. HLA provides a standard set of distributed M&S services and data interchange formats which, with appropriate expertise, can be used to achieve interoperability amongst HLA federates. HLA has also been standardised by IEEE [16].

In HLA, a group of simulations, or federates, needs to adopt a Federation Object Model (FOM) that identifies the interactions and attributes supported by the federation. Federates distribute data to other federates using software known as the Run Time Infrastructure (RTI). For federates to interoperate, they must be able to publish and subscribe to the same FOM and use the same version of the RTI.

Both DIS and HLA simulator interfaces need to be specified to the latest standards for maximum interoperability. For DIS, the latest standard IEEE 1278.1a-1998 should be specified to ensure backward compatibility with older systems, since each release of the DIS IEEE standard is compatible with previous versions. A minimum set of PDUs that should be supported by all ADF aerospace simulators is identified in [17]. These include the key PDUs from the Entity Information, Simulation Management, Emissions, and Radio Communications families to enable interoperability for entity interaction, warfare, electronic warfare, and communications.

If HLA is used, the recommended approach is to adopt the IEEE 1516-2000 standard. Legacy systems that use the HLA 1.3 specification should be upgraded to IEEE 1516. Further, these systems should use a Federation Object Model based on the Real Time Platform Reference FOM. The RPR-FOM provides a HLA representation of the DIS protocol and can simplify communication with DIS systems via DIS/HLA gateways.

Strategies for handling both DIS and HLA-compliant simulators are discussed further in [18]. For interoperability among both DIS and HLA compliant simulators, DIS/HLA gateways will be required to translate between the PDUs and RTI messages in real time.

TENA is an emerging standard that is being employed by the US training range community [5]. It can also be used for simulator intercommunication. Again, gateways between DIS/HLA/TENA can be created if interoperability with TENA-compliant systems is required in the future.

It should be noted that both the 1998 IEEE DIS standard and the 2000 IEEE HLA standards are being updated by SISO [6].

5.2 Voice Communications

Legacy simulators typically have radio communications and internal intercom capability. These communications systems generally emulate the user interface of the systems found on the original platform and may provide communications interoperability within the simulator. However such systems cannot generally communicate with the radio/intercom communications systems in another simulator since they are proprietary and do not comply with any industry standard.

The DIS Radio Communications PDU Family provides a simulator radio/intercom communications industry standard [14] and has been widely used. HLA, however, does not provide sufficient compliance at the required level so that any HLA communications system must be specifically designed to be interoperable. Alternatively, communications interoperability can be achieved through the use of a RPR-FOM solution. The usual HLA interoperability requirements must again be met.

Radio/intercom system interoperability among HLA/DIS system will also be required. Again this can be achieved through a specifically designed, proprietary solution or a DIS/HLA RPR-FOM based gateway solution.

5.3 Data Link

In real combat, military platforms coordinate their operations using tactical data links. Australian systems currently use Link-11 and are migrating to the newer Link-16 protocol.

In the simulated world, there are several ways to achieve this. Pseudo messages that emulate real link data can be exchanged or the real link messages can be used embedded into a suitable wrapper. This latter method has the advantage that simulated and real systems can exchange link data during an exercise.

Either the real data link information can be embedded into DIS/HLA messages, as is done in the emerging SISO standard for Link 16 [6], or the real data link messages can be wrapped into another protocol such as the NATO SIMPLE. This latter approach was successfully used by the RAN in the CReaMS 2001 – 2003 series of exercises [9].

5.4 Simulator Capability and Fidelity

When a simulator's capacity has been exceeded, additional externally generated entities may be ignored, leading to inaccuracies in representation of the synthetic battlespace. The Navy simulation systems at HMAS WATSON, for example, can handle several hundred entities in exercises. However not all systems are designed to handle so many entities. Careful exercise design will be needed to ensure that all systems can handle the required number of entities. This requirement should be specified for new simulation systems that will be employed by the ADF.

Different systems have different representations of the natural environment, frequently leading to mismatches in location and causing fair fight issues. One system may have a detailed radar model that requires target cross section while another only uses a range model. These differences need to be appreciated to avoid fair fight issues in distributed simulation exercises.

5.5 Networking Infrastructure

Networking infrastructure needs to be provided to link the ADF's simulators which are geographically dispersed among many bases and across different states. For Navy systems that include network-enabled FFGs, and later ANZACs and Air Warfare Destroyers, this will need to extend to several ports.

ISDN links can be employed but these are expensive. A more robust solution would make use of existing network infrastructure such as the Defence Wide Area Communications Network (DWACN). The Combined Federated Battle Lab (CFBL) network has also been used for international DSTO networking exercises.

Navy will need to provide the shore infrastructure so FFGs equipped with network-enabled On Board Training Systems can connect to the network and participate in distributed exercises with the aerospace simulators.

5.6 Encryption

In general, the ADF's training simulators have the ability to run classified exercises. Exercises linking training simulators will thus need to employ encryption. For the CReaMS international exercises, the data at each end in Australia and the US was encrypted using Motorola Improved Network Encryption Systems (INES) and then passed over the unclassified Australian Academic Research Network (AARNET) network [10].

6. POLICY AND MANAGEMENT ISSUES

6.1 Australian Defence Force

Within the Defence Department there are five relevant Defence Instructions for the use of simulation:

- Defence Instruction (General) DI-OPS-42/1 *Defence Simulation Policy* (2001) [19]
- Defence Instruction (Air Force) DI(AF)-OPS-5-17 (Amdt 1) *Royal Australian Air Force Training Simulator Policy* (2001) [20]
- Defence Instruction (Air Force) DI(AF)- OPS 5 –30, *RAAF Simulation Policy* (2001) [21]
- Defence Instruction (Navy) DI(N)-ADMIN 67–1 (Amdt 1) *Navy Policy on the Management and Employment of Modelling and Simulation* (2006) [22]
- Defence Instruction (Army) DI(A)-ADMIN-88-1 *Army Simulation Policy* (2005) [22]

The three service policies explicitly address the requirement for simulator interoperability and the use of standards. The Defence Simulation Policy refers to the need to combine simulations for collective training and carry out higher level analysis while the Navy policy refers to the MWTS for developing and testing advanced concepts.

6.2 US Air Force Distributed Mission Operations

Within the US, there are two large mature single-service programs that deliver collective training for Navy and Air Force namely the Battle Force Tactical Training (BFTT) program and Distributed Missions Operations (DMO) programs respectively. The DMO program, for example, adopts a rigorous approach to the requirements for standards and interoperability among different aerospace simulators [24]. This approach comprises:

1. *Interface standards* - network, DIS standard, RTI/FOM for HLA
2. *Integration standards* - event control, security, testing, data collection
3. *Federate system performance standards* – technical performance, synthetic natural environment, threat representation and CGFs, common models, visualization.

A similar approach will need to be adopted by the ADF to ensure that interoperability requirements are met, and that distributed exercises can be satisfactorily carried out. The work referred to in [12], 17] [18] addresses some of these issues.

7. CONCLUSIONS

The ADF has many aerospace training simulators, and is both upgrading current systems and purchasing new ones to assist with crew and tactical training. These need to be interoperable to facilitate advanced tactical training and mission rehearsal for future operations in a networked battlespace. This paper has briefly described the main systems of interest for such a networked synthetic battlespace and discussed the technical and administrative issues to enable full interoperability.

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