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THE EVOLUTION OF SIMULATION

THE NECESSITY FOR DISTRIBUTED MISSION TRAINING (DMT) IN MEETING FUTURE AIR FORCE FLYING REQUIREMENTS

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ABSTRACT

There currently exists a significant training gap for the CF fighter community between legacy stand-alone simulators and limited live flying training exercises, which are required to prepare crews for combat in a coalition environment. In keeping with the Strategy 2020 concept and the capability-based planning process, the CF needs to be innovative in its approach to training of combat crews and remain interoperable, embracing key technology advancements with our allies.

Utilizing network simulation technology, Distributed Mission Training (DMT) can bridge this gap, complementing existing flying hours and offering an alternative to the stand-alone simulators and limited frequency of critical Maple and Red Flag exercises. DMT allows individual, team and inter-team skills to be practiced among Wings, and other countries at local and long distance locations with missions comprised of highly complex synthetic environments and scenarios representative of Composite Air Operation (COMAO) packages. Distributed network technology has matured with the United States broadening its application to Distributed Mission Operations (DMO) which encompasses the future focus for most NATO and alliance forces of joint training of command and control units. Overall, DMT will help enhance interoperability and trust amongst coalition partners, which is vital to the foundation for future successful coalition combat operations.

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Strategy 2020 clearly indicates that DND must become more innovative to succeed in the emerging battlespace of the 21st century. This pro-active approach will help ensure that the Canadian Forces (CF) possess the flexibility needed to adapt to on-going changes in technology and the associated effect on international relations and alliances.[1] In response to this goal, a strategic capability planning (SCP) process has been implemented at NDHQ that directs planning towards a capability-based approach.

There have been dramatic changes to the strategic environment since the cold war era; planning has transitioned from being threat-based, to the defining of generic, but key

[1]Department of National Defence, *Strategy 2020* (Ottawa: DND Canada, June 1999), 5.

military capabilities. This SCP process seeks to provide the flexibility in finding the most effective way to provide a necessary capability.

In this construct, a key capability for our air force and military is the training and readiness of our fighter combat crews. The CF and its fighter force must be capable of working with our most likely coalition and alliance partners, while retaining an autonomous capability to act domestically.

It is proven that CF concept development and experimentation, in the area of modeling and simulation, must continue to focus on those aspects of *joint and combined* activity that allow CF formations to operate effectively with *coalition* and alliance partners.[2] This will require integration of new operational concepts and simulation into our training regime and exploitation of new technologies and skill development for complex joint and combined operations.[3]

Defence Research and Development Canada (DRDC) and its research allies are attempting to establish the efficacy of networked simulation, or distributed mission training (DMT), as a means in preparing our CF fighter force to work seamlessly and effectively with our allies in a coalition effort.

The United States has invested significant funding and development in the DMT program to date. Networked simulation has evolved into a mature technology and provides a highly effective training system and environment conducive to supporting the North Atlantic Treaty Organization (NATO) and other alliance/coalition combat crew readiness and training goals.

This essay will demonstrate that distributed mission training (DMT) has a critical role to play in addressing the challenges that face tomorrow's air force.

To support this thesis, the paper will provide an overall background on fighter aircraft simulation and training. It will transition

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[2]Department of National Defence, *Strategic Capability Planning for the CF*, 30 September 2003; available from http://vcds.mil.ca/dgsp/pubs/rep-pub/dda/strat/intro_e.asp; Internet; accessed 20 November 2003. Definition – *Joint* – NATO – an adjective that connotes activities, operations etc in which elements of more than one service of the same nation participate. Definition – *Combined* – NATO – an adjective that connotes activities, operations, organizations, etc between two or more allies.

[3]Department of National Defence, *Strategy 2020*…, 8.

chronologically from past to present DMT simulation initiatives and follow with a discussion on future simulation capabilities and functions. The evolution of DMT and its critical role for the CF will be described in the following, sequenced sections:

a. *Background of Simulation*;

b. *DMT and the CF Requirement,* which describes the training gap that currently exists between legacy stand-alone simulators and live flying exercises;

c. *DMT Concept,* which discusses mission capable and network capable simulators;

d. *DMT Training Concept Development,* which outlines individual, team and inter-team skills and the concept of Mission Essential Competencies (MEC);

e. *DMT Technical Capabilities*;

f. *Evolution of DMT – Previous Trials and Demonstrations*, which analyzes the various trials carried out in the United States, United Kingdom and recently in Canada;

g. *Advantages of DMT*;

h. *Challenges for DMT,* which includes a discussion on current limitations and provides an overview on standardized system architecture and performance measurement concerns;

i. *The Way Ahead – Current DMT Initiatives,* which analyzes the progress made in the United States, the NATO perspective, and outlines the Canadian initiatives such as the Canadian Advanced Synthetic Environment (CASE) Project and the CF-18 Advanced Distributed Combat Training System (ADCTS) Project;

j. *Future DMT Capabilities,* which discusses briefly the key aspects and requirements for mission rehearsal and deployability; and

k. *Distributed Mission Operations (DMO),* which describes the continued evolution and future expansion of DMT capabilities in a joint training context.

BACKGROUND

In the past, stand-alone fighter simulators were predominantly used for procedural training, which included key areas for instruction such as instrument flying, instrument approaches, checklist/emergency procedures and intercepts. Given the limited flying hours and low yearly flying rates (YFR), the simulator sessions were primarily aimed to improve the aircrew's individual skill and proficiency in order that hours could be used more effectively in the aircraft in a tactical environment. Currently, with the increased complexity of weapon systems, rising training requirements and increase in coalition operations, there continues to be limited and insufficient flying training opportunities (i.e., Maple Flag and Red Flag exercises) to fully prepare our combat ready crews to operate in a complex, coalition environment.

To fill this significant *training gap*, there have been dramatic improvements with respect to simulator capabilities and the reduced costs for advanced, distributed simulation technologies. With advanced networked simulation, the CF can immerse combat crews in comprehensive simulator missions, creating a sense of realism, by putting them under military control in a realistic operational theatre and flying in a coalition mission containing both friendly forces and credible threats. These scenarios can now be modeled in a collective training exercise in terms of timings and events and are not constrained by factors that limit live flying exercises such as geographic range location, number and type of available aircraft, varied threat systems, weather, and electromagnetic (EM) propagation.

In 1997, the U.S. Air Force Air Combat Command embarked on this revolutionary path for operational readiness training of its combat crews. This program, called Distributed Mission Training (DMT), creates a synthetic battlespace by networking flight simulators together in both local and wide area networks (WAN). As a result, operational squadrons located at geographically separated air force bases can practice combat skills and rehearse operational missions together. This capability to train on a daily basis in a realistic combat environment represents a major improvement in providing operational readiness resources to operational units.

DISTRIBUTED MISSION TRAINING AND THE CF REQUIREMENT

Figure 1 – Distributed Mission Training (DMT) Networked Simulator

To understand *Distributed Mission Training* (DMT), it is defined as a shared training environment comprised of live, virtual, and constructive simulations allowing war fighters to train individually or collectively at all levels of war (see figure 1- example of virtual simulation).[4] DMT allows multiple players at multiple sites to engage in training scenarios

[4]Distributed Mission Training, *Air Force Research L L Lte LearchhAit* *e* *e*

ranging from individual and team participation to full theatre-level battles. This combination allows nearly unlimited training opportunities for *joint and combined* forces from their home locations or potentially deployed sites. Training the way we fight recognizes that training is the peacetime manifestation of war.[5] This DMT training system can represent the total integrated mission that supports enhanced training opportunities for all war fighters.

Now, what is the requirement or need for DMT from a CF perspective? To set the framework, as stated in the CF Defence Planning Guidance (DPG), Canada is to "strengthen our military to military relationships with our principal allies ensuring *interoperable* forces, doctrine, and Command, Control, Communications, Computer and Intelligence (C4I) systems."[6] With the current asymmetric threat and the wide spreading revolution in military affairs (RMA), it is unknown when and where coalition forces will be required. As recently illustrated by the CF-18 participation in the 1999 Kosovo conflict and depicted in the DPG, a principal CF goal is to "manage our interoperability relationship with the United States and other allies to permit seamless operational integration at short notice."[7] With all the recent coalition taskings and those envisioned in the future, *interoperability* will continue to play a key role. As Group Captain Peach stipulated though, "regardless of concepts, doctrine, and technology, the essential requirement for success in a coalition is *trust*."[8]

One method through which trust and improved team performance can be accomplished is from coalition crews practicing together in a representative, wide-scale, war-setting environment. Modern coalition air operations and mission packages employ multiple assets in a variety of

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decision skills (i.e., committing fire control resources to action), or communication skills (i.e., as a member of a C4I team)

Definition -*Constructive Simulation* – Simulations that involve real people making inputs into a simulation that carries out those inputs by simulated people operating simulated systems. (i.e., computer generated forces)

[5]Distributed Mission Training, *Air Force Research Laboratory Mesa Research Site*…, 59.

[6]Department of National Defence, *Canadian Forces Defence Planning Guidance 2001* (Otttawa: DND Canada, 2001), 2-9.

[7]*Ibid*, 2-9.

[8]Stuart Peach, *Perspectives on Air Power* (London: Her Majesty's Stationary Office, 1998), 79.

roles. Besides strike and escort duties, other roles such as Command and Control (AWACS), Electronic Warfare (EW), Air-to-Air Refueling (AAR) and Suppression of Enemy Air Defence (SEAD) most likely will be required. All of these assets and their crews are required to work together to ensure mission success. In addition to crews honing their flying skills, increased demands also require greater proficiency of weapon system operation. A greater emphasis and balance needs to be placed on sensor manipulation, information management, situational awareness, decision-making and communication.[9] This is a complex training requirement that needs to be addressed by all players *practicing together*. In the past, the CF relied on live flying training exercises such as Red Flag and Maple Flag to provide the learning opportunities and the growth of *trust* and confidence in themselves and each of the coalition member's capabilities.

Red Flag Exercises, for example, were established in 1975 to allow aircrew the capability to sharpen aerial combat skills by providing realistic training in a combined, air, ground and electronic threat environment. A typical Red Flag exercise involves a variety of attack aircraft, which could include the following: fighter and bomber aircraft (F-15E, A-10, B-1), reconnaissance (Unmanned Aerial Vehicle - UAV), electronic countermeasure suppression aircraft (EC-130, EA-6B, F-16), air superiority (F-15, F-16, F/A-18), airlift (C-130, C-141, C-17), and aerial refueling aircraft (KC-130, KC-135). The E-3 Airborne Warning and Control System (AWACS) aircraft plays a significant role in this training by using its unique radar capability to monitor, co-ordinate and support many aspects of the blue force efforts.

The goal of the Red Flag exercise is for each crewmember to fly eight to ten missions during a two-week period as part of a blue force that can be tasked with a variety of targets of which 50 different types are available. The blue force crews are typically met by a red force of

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[9] Barry Tomlinson and Jan van Geest, *Aircrew Mission Training via Distributed Simulation – Progress in NATO,* 3. Paper presented at the NATO Research and Technology Organization (RTO) Studies, Analysis, and Simulation Panel (SAS) Symposium, Brussels Belgium, 3-5 April 2002.

F-16's mimicking tactics and techniques of potential adversaries. Red Flag exercises, as a minimum, will see employment of roles such as Defensive Counter Air (DCA), Offensive Counter Air (OCA), Interdiction/Close Air Support (CAS), Suppression of Enemy Air Defence (SEAD) and Command and Control.

The main tenet of Red Flag is being able to replicate the first ten days of war of a major tactical operation through a large employment of forces. This exercise focus is extremely important as gaining the initiative and overall control during the initial stages of war are demanding tasks and critical factors to wartime success. Red Flag opportunities provide crews with limited but essential experience, allowing combat ready crews the potential for improved survivability in future conflicts and battles.

The primary training audience for Red Flag is a blue four-ship aircraft formation up to a mission commander status. Through this U.S. inter-service and coalition training, Red Flag exercises allow the opportunity to practice employment tactics throughout a wide spectrum of tactical warfare with the opportunity to introduce aircrew to tactical enablers such as Rules of Engagement (ROE), Intelligence and Information Operations.[10]

Maple Flag, which is hosted by Canada at 4 Wing Cold Lake, is quite similar to Red Flag in that it provides a venue for comprehensive coalition training in a war type scenario. The benefits of these live flying exercises cannot be underestimated. These include working in large coalition packages with a diverse set of aircraft with varying roles and capabilities. The co-ordination and planning required among coalition participants in a live flying environment is an invaluable experience and must be continued. The various countries working together in the exercise gather an appreciation of their coalition partner's strengths and weaknesses, forming bonds and strong links for future coalition exercises or operations.

There are, however, several limitations and constraints with these live flying exercises. First among the limitations is the frequency of the events. For example, Maple Flag is conducted once annually while Red Flag at Nellis Air Force Base has only four annual exercises, of which two are primarily dedicated to U.S. aircraft only. To fully appreciate the significance of this limitation, it is important to know that the training cycle for U.S. aircrew to attend a Red Flag is forecasted once every 15-½ months, while Canadian fighter crews can expect, on average, to participate in only *one Red Flag exercise* during an operational flying tour. This clearly does not provide crews with sufficient training opportunities that encompass all the requirements of a complex network of systems.

A second critical limitation is the operating and support costs of the exercise. As one can imagine, there is considerable work and personnel involved in preparing and operating an effective and safe exercise. With the high costs of planning and running these events, Canada recently implemented cost recovery measures based on sorties flown by coalition countries in Maple Flag. With respect to a CF-18 four-ship contingent deployed to a Red Flag exercise for a two-week period, costs are approximately $225,000 Canadian (plus sortie fees and aircraft associated hourly costs).[11] The Red Flag deployment would consist of approximately 15 pilots, and be supported by 70 personnel.[12]

The last limitation that will be highlighted is operational tempo. Scheduling of resources (i.e., aircraft and personnel) continues to be problematic for large training exercises with frequent over-tasking and resulting competing priorities. It was seen recently that the Red Flag Exercise originally scheduled for January 2004 was cancelled due to real world taskings (i.e., Operation Iraqi Freedom). Canceling this Red Flag exercise freed up 24 units and nearly 2,800 personnel

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[10]Red Flag Exercise; available from http://www.aleinn.com/info/flag_tenets.html; Internet; accessed 04 February 2004.
[11]Officer in Charge Air Force Tactical Training Center, 4 Wing Cold Lake, e-mail received by author, 02 March 2004.

for deployed taskings.[13] These coalition training exercises and the associated high costs and magnitude of personnel involved, make it unrealistic in increasing the frequency of these large, live flying exercises. It is essential that we obtain other means to train our crews in a coalition setting to ensure that *crew performance*, *interoperability* and *coalition trust* is maintained.

In order to derive greater benefit from these live flying training exercises, Canada acquired a fully autonomous Air Combat and Maneuvering Instrumentation (ACMI) system in February 2001. Using Global Positioning System (GPS) technology, the ACMI system allows pilots to train autonomously in any available airspace without reliance on a fixed or tethered[14] range. This upgraded ACMI system greatly enhances Dissimilar Air Combat Training (DACT) among allied countries allowing live controllers to track up to 72 high activity aircraft in real time. These mobile pods, with rangeless technology, collect in-flight data for both real-time tracking and post-mission debriefs. These ACMI pods currently help with training for both daily CF-18 squadron level operations as well as the annual multinational Maple Flag exercise.[15] Although currently these pods only provide time, space and positional data for squadron crews in the air-to-air role, the information has proven quite beneficial for debrief and feedback purposes. When Engineering Change Proposal (ECP) 58 and associated Operational Flight Program (OFP) changes are fully implemented on the aircraft, the crews will be able to review all weapons employment, radar information and real time kill notification.[16] This progress recognizes the value of live training and attempts to maximize its benefit by enhancing feedback. However, despite this significant advance, live training in general suffers from the following limitations:

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[12] *Ibid*.
[13] Red Flag Exercise; available from http://www.globalsecurity,org; Internet; accessed 04 February 2004.
[14] Hyper Dictionary; available from http://www.hyperdictionary.com/dictionary/tethered; Internet; accessed 04 April 2004. Definition – *Tethered* – bound; confined or restricted with, or as if with a rope or chain.
[15] Maple Flag Exercise; available from http://www.cubic.com/corp/news/pressreleases/ 2002/maple_Flag_Final.htm; Internet; accessed 04 February 2004.
[16] Directorate of Aerospace Requirements (DAR) 5 – CF-18 Project Staff, e-mail received by author, 09 February 2004.

> "increasing pressure to reduce flying training costs, restrictions on airspace and lack of adequate training ranges, operational factors such as improved weapons system performance capabilities, security constraints on the use of electronic warfare systems, mission complexity and rules of engagement, environmental and safety restrictions including the inability to fire weapons or use chaff/flare, weather, and an unrepresentative mission environment, with no threats that fire back."[17]

With the reduced YFR and the limitations for actual flying events highlighted above, air combat training's emphasis on higher order weapon system employment skills will require a method to focus co-ordination, communication and complex judgment in a coalition environment. Unfortunately, legacy stand-alone simulators are not providing the alternative needed.

Like live flying training exercises, current stand-alone simulators also have limitations. The current simulators are being exploited to their full capability and potential but due to their older technology and stand-alone architecture, they cannot accomplish all the tasks and objectives required in today's demanding training regime.

From a CF perspective, during initial fighter training at 410 Squadron Operational Training Unit (OTU) in Cold Lake, only half of the sorties are usually accomplished in the stand-alone simulator. This currently consists of 30 simulator sessions for each student pilot per course. When the pilot graduates and transitions to an operational squadron with a limited combat ready status, the monthly requirement, for an inexperienced wingmen, is one sortie in the simulator every 30 days. This simulator session is only used for monthly currency missions, with its primary focus being abnormal and emergency procedures. The employment of current stand-alone simulators in this context makes perfect sense given the simulators known limitations, capabilities and finite potential. There is a significant disparity, however, between

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[17]Tomlinson and Van Geest, *Aircrew Mission Training via Distributed Simulation – Progress in NATO…*, 3.

current stand-alone simulator capabilities and what a simulator has to do in preparing crews for the current dynamic environment. It is proposed that much more training needs to be accomplished with simulation than is currently capable with the legacy, stand-alone systems.

With the current stand-alone simulator limited capability, simulators have not been considered a critical part of an operational fighter squadron's combat readiness training program. The utility of current flight simulators to operational fighter pilots have been limited for several reasons. The first reason is the difficulty of providing a realistic-out-of-the-cockpit visual display. The second reason is the simulation model. The air combat environment is considered by most pilots to be dynamic and variable. With aircraft aerodynamic and systems models, simulators require additional complex computer simulations and databases that represent the air combat environment. These aerodynamic and system models could include surface to air missiles, radars, and terrain models, all of which have seen significant improvement and advancement over the last decade. One area and limitation that falls beyond the scope and capability of stand-alone simulators is basic fighter tactics.

Fighters are almost always employed in flights of two or four aircraft, as a minimum. This practice dates back to World War I. In 1916, Oswald Boelcke reasoned that single pilots were highly vulnerable to surprise attack and that fighters should fly in pairs so that each could cover the blind spot of the other. The origin of formation flying was thus based on mutual support and protection.[18] This basic formation concept was later developed into flights of four and formation packages to accomplish a mission. It must be highlighted that most mission packages attack systems of targets with aircraft sequenced and integrated to ensure self-protection. Therefore, to be useful to readiness training and preparing for a coalition environment, flight simulators must have a high degree of fidelity and be *networked* together to support flight and composite force training. This is currently not the case for our CF-18 aircraft training program and is a significant limitation and void that exists in the combat training regime.

Therefore, the CF must be able to bridge the gap between legacy simulator systems and the rare live Flag coalition exercises that currently exist. This is a *critical role* distributed mission training (DMT) could play for the CF-18 fighter community in its preparation for coalition operations and in addressing key interoperability concerns. Embracing this combat readiness training role, DMT can also complement existing flying hours and offer an alternative to the stand-alone simulators and the limited live flying exercises.

DISTRIBUTED MISSION TRAINING (DMT) CONCEPT

For simulators to be networked in a DMT environment, they need to be both mission capable and network capable. Mission capable refers to manned simulators, which must have sufficient fidelity to allow pilots to train as they intend to fight and to perform their mission tasks in a valid manner. Mission capable requires that the aircraft cockpit, flight performance, sensors and weapons be simulated to an appropriate level of physical and functional fidelity.[19] Network capable refers to a manned simulator that is capable of exchanging data in a secure manner with other participating simulations, using an agreed upon protocol.[20] The participating simulators must be interoperable with one another within a common synthetic environment such that the

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[18]Department of National Defence, CFACM 2-322 *Canadian Forces Fighter Aircraft: History, Development and Tactics* (Winnipeg: DND Canada, 1990), 1-14.
[19]Tomlinson and Van Geest, *Aircrew Mission Training via Distributed Simulation – Progress in NATO…,* 4.
[20]Clark, Ryan and Zalcman, *Advanced Distributed Simulation for the Australian Defence Force…,* 72.
Definition - *Protocol* – a set of rules governing a data communications procedure that must be followed to enable two or more computing devices to exchange and read instructions and messages.

cause and effect relationships in the synthetic world correspond to the cause and effect relationships in the real world.[21]

In theory, DMT involves a shift in the goals of training from direct control of an individual learning psychomotor and procedural skills to indirect control of large numbers of individuals executing hierarchically nested sequences of psychomotor, procedural, cognitive, and team skills in fluid, rapidly changing environments.[22] With the DMT theoretical approach established, the training concept and its use must be developed.

DISTRIBUTED MISSION TRAINING CONCEPT DEVELOPMENT

Today's military forces operate within a battlefield that is increasingly lethal and complex. Tighter linkages between sensors (i.e., AWACS and Joint Surveillance Target Attack Radar System (JSTARS)) and shooters (i.e., fighters) require increased emphasis on *teamwork* for successful mission execution. DMT in the United States has been mainly focused on team training. Team training is the hierarchy of individual, team and inter-team skills needed by war fighters to engage in team combat.[23] The individual member needs to keep his proficiency in individual high-end skills (i.e., tactical formation) and effective employment of weapons systems in a team combat environment. Team skills include the collective skills needed to execute missions effectively. These team skills are usually well defined and can include, for example, 2-ship elements, 4-ship flights or an AWACS mission crew. *Inter-team skills* include the composite skills needed to execute missions and can include, for example, an interdiction mission conducted by a composite force. These types of missions are usually a limited tasking of different types of units that take place during Maple Flag or Red Flag coalition exercises. The

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[21] Tomlinson and Van Geest, *Aircrew Mission Training via Distributed Simulation – Progress in NATO…, 4*.
[22] Herbert H. Bell, "The Effectiveness of DMT," *Association of Computing Machinery (*September 1999): 6.
[23] Robert M. Chapman, *Development of Distributed Mission Training Operational Training Concepts,* 11-6. Paper presented at the NATO Research and Technology Organization (RTO) Studies, Analysis, and Simulation Panel (SAS) Symposium, Brussels Belgium, 3-5 April 2002.

individual, team and inter-team skills are all closely linked in missions with importance varying by phase of flight, and all are critical for DMT training success.

Building on this team-training construct, from 1999 to 2001, the United States produced a broad, conceptual structure for the application of DMT training. The term Mission Essential Competencies (MEC) was developed with the aim of capturing the dynamics of the combat mission environment. MECs were to define the specific knowledge, skills and related experience that are required for successful combat mission performance. For example, with the F-15C, analysts were able to reduce a task list of several hundred items for the F-15 fighter to seven distinct MEC competencies, which were oriented to their primary role and dynamics of air-to-air combat.[24]

To note, MEC is defined as "higher-order individual, team and inter-team competencies that a fully prepared pilot, crew or flight requires for successful mission completion under adverse conditions and in a non-permissive environment."[25] MECs represent an advance in how researchers and operational war fighters think about and define what it means to be *combat ready*. The MEC structure provides an organizing framework to guide the DMT capability to monitor and assess data relevant to numerous performance requirements in each exercise. The key aspect and goal of MECs is to utilize the DMT resource effectively to provide a sufficient building block approach to training for combat ready crews and to provide appropriate feedback through structured assessment.

In applying MECs, it is important to keep in mind that combat proficiency requires exposure to several different and increasingly complex training environments. Once a proficiency level is achieved, additional repetition versus the law of diminishing returns must be strongly considered. If a proficiency at a lower level is lost, however, the skill levels above may

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[24]*Ibid*, 11-8.

collapse due to the associated foundation eroding away. With DMT theory and concept development being established for this focused team training, the overall DMT qualities and technical capabilities need to be analyzed.

DISTRIBUTED MISSION TRAINING TECHNICAL CAPABILITIES

Over the past seven years, DMT technology and personnel experience have matured to a sufficient level achieving the requisite technical capabilities and establishing the necessary requirements for successful networked simulation.

Computing power has now been attainable, communication networks have significantly improved, and satellite and digital imagery has allowed enhanced, realistic terrain databases to be created worldwide. Computer generated forces (CGF) can now be used to augment the scenarios and the piloted platforms, to provide additional blue force assets and, if necessary, active red air and ground based air defence (GBAD) systems.

Interactions and sensors are fundamental elements of the distributed training environment. Sensors can now react realistically and provide high-fidelity interaction among the tactical entities. The synthetic natural environment (SNE) is well represented with the geophysical environment of the battlespace including detailed terrain, natural features, and atmospheric/weather conditions. These enabling technologies have made it possible to build realistic and challenging scenarios in a synthetic battlespace.

To co-ordinate and successfully implement networked simulation missions, DMT utilizes the set-up of a multi-ship simulator training facility. DMT involves a system that supports the crews in all phases of the complete operational cycle. The DMT cycle includes the issue of the Air Tasking Order (ATO), the planning/briefing phase, flying the actual missions in the

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[25] *Ibid*, 11-7.

simulators, and post mission debriefing, which includes the review of captured data for effective training *feedback*.

Exercise management personnel are critical for setting-up, controlling and using the network of simulators. In order that the training objectives are met, the personnel in charge of the training process, often referred to as the white force, must design, implement and test realistic, exercise scenarios. When the exercise/scenario is proceeding, the white force may inject trigger events to promote training in critical areas such as threat avoidance. For training, the facilities must allow the trainees to do all the planning, briefing, execution, and debriefing activities necessary to receive maximum benefit from the synthetic mission. Therefore, the individual sites need to be connected not only during the execution of a mission but also during planning, briefing and debriefing activities.

A requirement for a distributed training environment is a wide area network (WAN) with sufficient bandwidth and low latency to support real-time, man-in-the-loop simulation and data sharing.

Most exercises and missions will be carried out at the classified level with the threat parameters and aircraft/equipment capabilities of a sensitive nature. This involves the development of a sound security plan that involves all parties requiring an accreditation for the classification level desired and the encryption of data transmitted among sites. With this general appreciation of a DMT network and its capabilities, it is useful to review previous DMT trials and the evolution of distributed networked technology.

EVOLUTION OF DMT - PREVIOUS TRIALS AND DEMONSTRATIONS

UNITED STATES

To date, the United States has provided the most significant development in distributed network technology. Houck, Thomas and Bell investigated as early as 1991 the potential value of multi-player simulation for training F-15 pilots and Air Weapons Controllers using simulators designed for engineering development. This engineering research demonstrated that multi-player simulation provides valuable training for individual skills that are required in a team construct, which include communication and maintaining situational awareness.[26] Crane replicated these findings in 1994 using low cost, distributed systems based on Simulator Network (SIMNET) architecture. In 1996, Bell demonstrated the effectiveness of distributed simulation for training combined air and ground operations and close air support (CAS). These studies found that training payoffs are a function of both simulator capabilities and opportunities for aircraft training. Greatest training benefits from DMT are realized under the following conditions:

a. the simulators provide required levels of functional fidelity;

b. the aircraft training opportunities are severely constrained; and

c. the simulator training events are designed to take best advantage of the system capabilities.[27]

In the process of laying the groundwork for DMT, two early training exercises in the United States, Road Runner in July 1998, and Coyote in November 1998, confirmed the operational viability of the DMT concept. Through the Air Force Research Laboratory (AFRL) in Mesa, Arizona, exercise Road Runner and Coyote showed promise linking U.S. F-16 and F-15 simulators interactively with a command and control center via an AWACS simulator located in Tinker, Oklahoma. The trials conducted a variety of air-to-surface missions and DCA air-to-air missions. Road Runner aircrew participants reported that the DCA mission in a beyond visual range (BVR) environment was the best combination of exploiting DMT strengths, avoiding

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[26]Peter Crane and Herbert Bell, *Similarities and Differences in the Implementation of Distributed Mission Training,* 1. Proceedings of the Interservice/Industry Training, Simulation, and Education Conference (I/ITSEC) 2002 Conference.

[27]*Ibid*, 1.

weaknesses and complementing aircraft training. Surface attack missions were judged much less useful for DMT in that they replicated range-training events. Reports from these early trials indicated limited and incomplete out-the-window visual imagery, and that both surface and air targets were difficult to see at tactical ranges. Based on the results of these trials, AFRL focused their DMT engineering effectiveness studies on BVR multi-ship, multi-bandit, dissimilar air combat tactics training including DCA and OCA missions.[28]

In 1999, a demonstration was planned at the Air Force Association (AFA) Technology Exposition to demonstrate an international DMT capability between the United States and the United Kingdom using currently available products and technology. The overall aim was to determine the utility of using real-time distributed networks to augment *coalition training*. Another goal was to determine the potential utility of including command, control, intelligence, surveillance and reconnaissance (C2ISR) assets. AFRL wanted to show that effective integration of C2ISR assets into a real-time, international distributed simulation network could significantly enhance its training value by providing the capability to train the entire sensor-to-shooter mission. Lessons learned from this 1999 exposition were that you could successfully execute real time mission simulations involving a number of geographically dispersed sites (i.e., including limited C2ISR assets) in the United States using the internet and that it was possible to use both a point to point encryption device and the internet with Distributed Interactive Simulation (DIS) multicast protocols. Unfortunately, the 1999 exposition had difficulties obtaining dedicated international data lines in a large metropolitan area (Washington) and the communication connection to England had to be cancelled.

[28]*Ibid*, 2.

In 2000, after further study and use of a primary rate Integrated Services Digital Network (ISDN), a trial was scheduled with three networked sites planned in Washington, Mesa, Arizona, and Crawley, England. The objective was to demonstrate the utility of using DMT for international, inter-team training involving C2ISR assets, decision makers and shooters. The goal of this exercise was to successfully accomplish the six stages of the kill chain – Find, Fix, Track, Target, Engage, and Assess.[29] The researchers used DIS protocols to achieve interoperability, determining a common method of time stamping and determining the average latency[30] between Mesa and Crawley, England. Simulator assets linked in this Nellis Range database demonstration included F-16, A-10, JSTARS, Tornado, Predator UAV, an AWACS director and a Combined Air Operations Center (CAOC). The scenario included OCA, interdiction, Combat Air Patrol (CAP), SEAD, time critical targeting, and battle management from AWACS and JSTARS. The 2000 exposition and the DMT scenario was a big success story with well executed scenarios, crystal clear voice traffic and average latency between the U.S. and the UK ranging from 148 to 198 millisecond, well within acceptable limits.[31] *It was demonstrated that long-haul network environments were feasible and that the international DMT long-haul connections could be expanded to NATO and coalition partners.*

UNITED KINGDOM

In the U.K. meantime, national synthetic experiments for distributed networks took place commencing in the year 2000. The U.K. focus was on Composite Air Operations (COMAO) incorporating both air-to-air and air-to-ground operations in a large package of aircraft typical of actual deployments (see figure 2). A COMAO is defined as "air actions, inter-related in both

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[29]David A. Greschke and Herbert H. Bell, *Training for Dynamic Aerospace Control: An Experiment in International Distributed Mission Training*, 20-3. Paper presented at the NATO Research and Technology Organization (RTO) Studies, Analysis, and Simulation Panel (SAS) Symposium, Brussels Belgium, 3-5 April 2002.

[30]Clark, Ryan and Zalcman, *Advanced Distributed Simulation for the Australian Defence Force…,* 70. Definition - *Latency* – The portion of overall transport delay (time), which is in excess of delays in the actual vehicle being simulated.

timescale and space, where units differing in type and/or role are put under the control of a single commander to achieve a common, specific objective."[32] The U.K. application emphasized planning and co-ordination activities that occur before flying the mission, as well as flying and debriefing.[33]

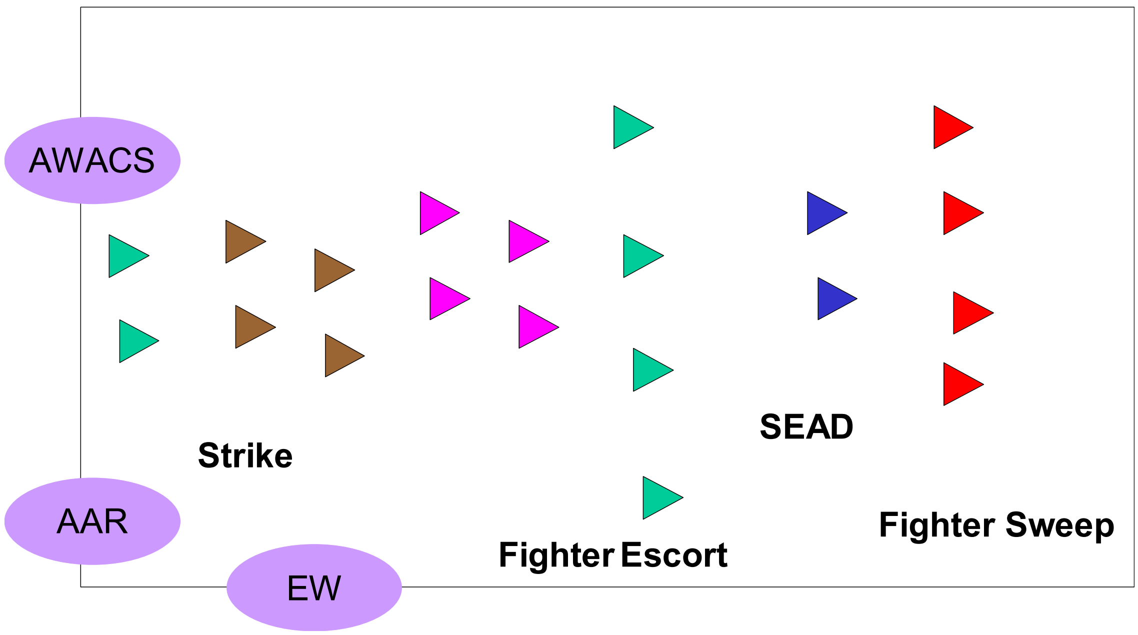

Figure 2 – Typical Composite Air Operation (COMAO) Package

TRIAL EBB AND FLOW AND TRIAL SYCLONE (U.K.)

The U.K. Exercise Ebb and Flow in February 2000 and Exercise Syclone in January 2001 involved aircrew from front-line squadrons, representing different roles. Simulators were networked together in the U.K. enabling four ground-attack pilots and four air-to-air aircrew to

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[31]Greschke and Bell, *Training for Dynamic Aerospace Control: An Experiment in International Distributed Mission Training*…, 20-12.

[32] Heather McIntyre, Ebb Smith, and Winston Bennett, *Exploiting High Fidelity Simulation for Aircrew Coalition Mission Training*, 2. Paper presented at the NATO Research and Technology Organization (RTO) Studies, Analysis, and Simulation Panel (SAS) Symposium, Brussels Belgium, 3-5 April 2002.

[33]Crane and Bell, *Similarities and Differences in the Implementation of Distributed Mission Training*…, 6.

interact together under the direction of an AWACS fighter controller. This was accomplished in realistic multi-aircraft missions, within a high threat environment, as part of a synthetic COMAO exercise. The scenario and missions were based on a real operational theatre and were designed to exercise the *inter-team skills* of the aircrew. The co-located aircrew were exposed to a complete mission cycle which included planning, briefing, flying and debriefing under the supervision of a white force member with an issuing of an ATO and was designed to exercise real tactical interactions among participants. Remotely based teams were used to represent manned, hostile, air threats using a wide area network (WAN). The aim of this research was to look at the potential of synthetic environments to provide *collective training* for front-line aircrew. Collective training, as defined by NATO, involves " two or more *teams*, where each team fulfils different roles, training in an environment defined by a common set of collective training objectives (CTOs)."[34] To follow, a team is defined as "a number of individuals who may have different tasks within that team but whose operational remit are to fulfill a specific role (ie, a tactical four ship in a ground-attack role)."[35]

The results of these trials (Ebb and Flow, Syclone) indicated that a well-designed synthetic training exercise has the ability to fulfill the collective training needs of front-line aircrew *to a level that is comparable* to the training achievable in a live flying event. For example, for ground attack, networked simulation provided acceptable training for a number of role-specific, mission related tasks which included precision munition employment, surface to air missile tactics/countermeasures, interaction with AWACS personnel, medium level tactics, communication jamming, Anti-Aircraft Artillery (AAA) tactics/countermeasures and multi-

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[34]Heather McIntyre and Ebb Smith, *Collective Training for Operational Effectiveness,* 21-1. Paper presented at the NATO Research and Technology Organization (RTO) Studies, Analysis, and Simulation Panel (SAS) Symposium, Brussels Belgium, 3-5 April 2002.
[35]*Ibid*, 21-2.

ship/package tactics.[36] In addition, it was found that collective training in the simulator enhanced participants' knowledge and understanding of what others do and how to work with them. This included enhancement of collective skills such as co-ordination and communication, and increased *confidence and trust* in other teams' capabilities. Advantages to these trials included aircrew being able to test out their responses to unanticipated attacks and the White Force, with overall exercise management, being able to give a gods-eye-view of the air picture, controlling the mission tempo, and having the opportunity to evaluate and assess the aircrew performance throughout all mission phases.

It was determined in the U.K. trials, however, that many benefits were the result of co-location of participants. The personnel playing the air-threats, who were remotely situated, felt out-of-the-loop, receiving inadequate briefings, with poor situational awareness. The knowledge, trust and confidence, borne out of personal contact, created a powerful bond which should not be underestimated nor undervalued when assessing the training needs for an effective, combat ready, multi-component package. On this basis, it was concluded that a critical assessment of how technology, including video links that can be used to support all mission phases for non-co-located teams, should be conducted.[37] Another consideration was that this exercise was based on only two different roles. As the scale of exercise increases, there may be a decrease in training effectiveness due to the difficulty in achieving multiple training objectives while operating under greater technical and organizational risk.

CANADIAN TRIAL PARTICIPATION

Since September 1999, Defence Research and Development Canada (DRDC) has worked closely with the United States under a Technology Research and Development Program - Project Arrangement (TRDP PA). The aim of this project is to help the CF embrace the concepts of

[36] *Ibid*, 21-6.
[37] *Ibid*, 21-16.

DMT in achieving the air force's training objectives, which include *interoperability with allied partners.* With a CF-18 simulator on location at DRDC Toronto as of November 2003, this Advanced Distributed Mission Training Technology Demonstration project continues to research and help address such areas as inter-simulator networking issues, visual display fidelity and determining the appropriate mix of simulator and in-flight training.

TRIAL VIRTEGO (U.S., U.K., CANADA)

In a chronology of events dating back to November 2001, AFRL (Mesa, U.S.), QinetiQ (Bedford, U.K.) and DRDC Toronto conducted the first in a series of trilateral simulation trials to investigate the potential of an international collective environment for real-time, ground-based aircrew. In comparison with previous U.S. DMT research, which focused on four-ship mission effectiveness and tactical employment for air-to-air and air-to-ground engagement missions, this U.K. led exercise focused on composite force missions.[38] VirtEgo was also to further study previously highlighted U.K. concerns of brief/debrief system technology and large package/multi-role scenarios. The simulated missions were similar to a real operational tasking, with full pre-sortie briefings, crew planning, sortie execution and debriefing, all conducted via a secure long-haul network[39] among the three countries. VirtEgo simulated missions included a secure, international distributed simulation network to include real-time, human-in-the-loop (virtual) simulators, computer generated forces (CGF) and systems for conducting distributed mission planning, briefing, replay and debriefing.

Overall, this trial conducted an international training exercise to evaluate the utility of distributed simulation technologies in providing training and to assess the effectiveness of

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[38]McIntyre, Smith and Bennett, *Exploiting High Fidelity Simulation for Aircrew Coalition Mission Training…*, 10.

training in preparing pilots for live COMAO exercises.[40] This VirtEgo trial was carried out in support of preparation for the live flying phase of the RAF's Combined Qualified Weapons Instructor (CQWI) Course. This course has similarities in content to the CF's Fighter Weapons Instructor Course (FWIC) given in Cold Lake.

The VirtEgo scenario was based on a real-world operational theatre with a synthetic coalition mission package which consisted of a manned U.S. four ship of F-16Cs, manned UK four-ship of Jaguars (Air-to-Ground role), manned UK four-ship of Tornado F3s (Air–to-Air role), and a large number of computer generated forces (approximately 40 air assets, 20 ground threats) which included four F-16CJs in the SEAD role and an EA-6B as an escort jammer. Canada participated as a stealth viewing node on the network as an initial step in participation in future coalition simulation training exercises. DRDC staff viewed and observed all stages of the trial including the briefing and debriefing phases.

The scenario was designed to cover two mission-training days. After a familiarization day, the first scenario was a medium level Thermal Imaging Airborne Laser Designator (TIALD) mission against a fixed facility. The second scenario was a medium level TIALD mission against a deployed SCUD.[41] The exercise was run like a live exercise with the white force overseeing the planning, briefing, execution and debriefing of the mission and ensuring that safety was not compromised. The white force, which is commonly referred to as the team of experts who organize and run large-scale live, training exercises, consisted of a CAOC element, AWACS director, Air-to-Ground and Air-to-Air experts and Intelligence experts.[42] The white

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[39]Clark, Ryan and Zalcman, *Advanced Distributed Simulation for the Australian Defence Force…,* 75. Definition – *Long-haul Network* – A network connecting computing devices and peripherals over long-distances. The transmission medium is usually a long-distance carrier but can also be a private-dedicated network.
[40]*Final Report on Trial VirtEgo: Training Coalition Forces Using Distributed Simulation*, 18 September 2002, 2. Paper presented at the NATO Research and Technology Organization (RTO) Studies, Analysis, and Simulation Panel (SAS) Symposium, Brussels Belgium, 3-5 April 2002.
[41]SCUD is not an acronym but refers to a short-range liquid propellant surface to surface ballistic missile.
[42]*Final Report on Trial VirtEgo: Training Coalition Forces Using Distributed Simulation…*, 8.

force incorporated into these scenarios impromptu, trigger events that challenged the aircrew. These included intelligence updates, radio communication jamming, munitions unavailability, system malfunctions and engagements by previously unknown GBAD sites.[43]

For every hour spent flying in the simulator, five hours were spent in briefing, planning and debriefing sessions. Each day of the exercise included the issue of an ATO, the presentation of weather and intelligence briefings, an aircrew planning session, a mass briefing, followed by a formation brief before pilots took to the simulators. Debrief sessions were conducted for the individual squadrons and the package as a whole, followed by a mass debrief conducted by the Mission Commander.

The brief/debrief stations at AFRL in Mesa and Bedford in the U.K. included video teleconference equipment, SMARTBOARD digital whiteboards, Microsoft NETMEETING software, microphones and loudspeakers (see figures 3 to 5). The use of the video link required careful control of scene content to retain acceptable system performance.

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[43]David Greschke, Edward Mayo, and Stuart Grant, *A Complex Synthetic Environment for Real-Time, Distributed Aircrew Training Research,* 1. Paper presented at the NATO Research and Technology Organization (RTO) Studies, Analysis, and Simulation Panel (SAS) Symposium, Brussels Belgium, 3-5 April 2002.

Figure 3 – Brief/Debrief System at AFRL in Mesa, Arizona

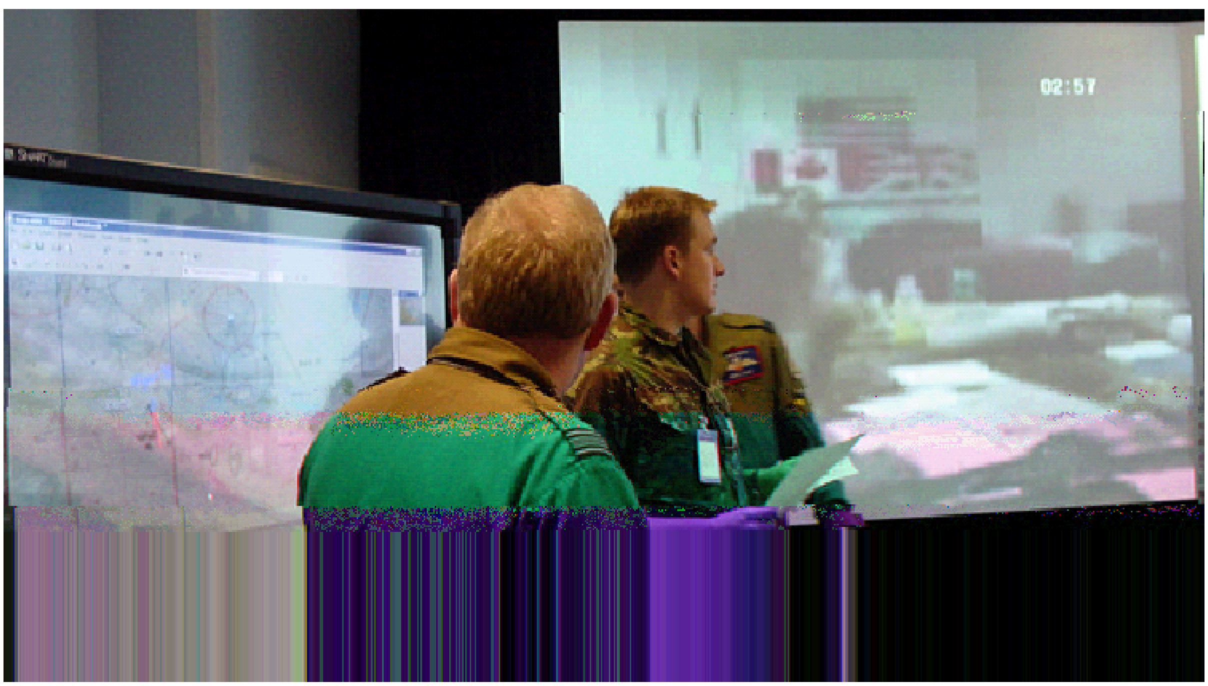

Figure 4 – U.K. – SMARTBOARD and Video-Teleconferencing Equipment in use during Mission Planning and Briefing/Debriefing.

Figure 5 – U.K. – Brief/Debrief Screens in use during Trial VirtEgo (i.e., Mass Debrief)

Overall, the missions achieved their objectives and the exercise was deemed a success. With the White Forces' gods-eye-view of what was happening and their knowledge of what the aircrew had planned, *they could manipulate conditions for maximum training value, something that is not possible in a live training exercise.* The communication infrastructure and data lines were used to carry out several mission briefings/debriefings, transferring all the simulation data, and all the digitized voice traffic among crews and other trial personnel. The average latency between North America and the U.K. was in the order of 190milliseconds (ms), well within the desired 240ms for DIS architecture. Trial VirtEgo demonstrated that synthetic COMAO provides good opportunities for crews to train and practice their Mission Essential Competencies (MEC). Aircrew participating in the trial were of the opinion that 60 percent of their role-specific MEC's could be trained in a synthetic training exercise as well as they could be trained in a regular live training exercise. There was an average 20 percent improvement seen in the aircrews' collective performance over the two mission days. The performance was assessed according to criteria such as ability to balance risk, level of awareness of the tactical situation, and the key aspects of communication and coordination.[44]

Some of the concerns highlighted in the VirtEgo exercise included Canada having difficulty in preparing their site for the processing of classified data. The long distance provider (not DRDC) had made several errors in configuring the T1 line between the U.S. and Canada. A second concern was that on day two, the performance of the computer generated adversary forces in the simulation exercise behaved unrealistically by flying too fast, turning too quickly and shooting unbeatable missiles.

Another concern highlighted was the technological limitations encountered with the brief/debrief link. Limitations included the following:

a. the reduced quality of the digitized video;

b. the wide area microphone and loudspeaker system encountered echos two to three seconds later; and

c. the headset mounted microphone limited discussions to only the person wearing it.

To note, the crews, when planning, showed a preference in using digital cameras, telephones and fax machines to utilize their conventional planning tools across the long distances rather than employing the newer technologies.[45] This planning included using a whiteboard and zooming the digital camera in on the maps. This set-up allowed all participants to greatly increase their level of interaction amongst other players.

The primary goal of the VirtEgo exercise was to understand what is required to turn a network of simulators into an effective collective training system. Despite some difficulties experienced during the mission, aircrew and white force concluded that as a result of this

[44] *Final Report - Trial VirtEgo: Training Coalition Forces Using Distributed Simulation*…, 16.

distributed simulation training, *increased cooperation and confidence were demonstrated between coalition forces during mission planning, flying, debriefing and feedback sessions.*[46] Key technical challenges that need to be addressed include developing means to mitigate the effects of communication lags on interacting, real-time simulators, and developing systems that allow geographically separated participants to collaborate seamlessly in mission planning, briefing, replay and debriefing.

Running this exercise was a tremendous step forward in coalition force training capabilities. Successful results of this trial set the stage for further research on coalition mission training research (CMTR). An International Project Arrangement under the Technical Training Co-operation Program (TTCP) was put in place after the VirtEgo trial to collaboratively conduct research and development activities that would enhance technologies, processes, and training strategies for applying distributed simulation training to coalition operations. Specific objectives of this TTCP project include the following:

a. expand distributed simulation to intercontinental distances;

b. develop systems to mitigate difficulties caused by extreme long distance links;

c. establish processes for creating scenarios to fulfill specified training objectives and develop metrics for determining impacts of training;

d. implement systems for distributed mission planning, briefing, and debriefing; and

e. assess the effectiveness of distributed simulation for enhanced war fighter skills in conducting coalition force operations.[47]

DRDC CF-18 MULTI-TASK TRAINER DEMONSTRATION

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[45] *Ibid*, 16.
[46] *Ibid*, 21.
[47] *Ibid*, 26.

During the week of 17-21 November 2003, I had the opportunity to witness a DMT training session at DRDC Toronto. DRDC had just received a high-fidelity[48], CF-18 Multi-Task Trainer (MTT) built by AFRL in Mesa, Arizona (see figures 6 and 7). The trial included networking with three F-16 MTT's in Mesa. The Instructor Operating Station (IOS) was well set-up at DRDC Toronto and included the following displays: overall tactical air display, cockpit instrument and displays of the CF-18, Next Generation Threat System (NGTS) display, and Heads-Up Display (HUD).

Figure 6 – CF-18 Multi-Task Trainer (MTT) and Instructor Operator Station (IOS) at DRDC Toronto

[48]Department of National Defence, *Statement of Operational Requirement - CF-18 Advanced Distributed Combat Training System (ADCTS) project 00000113* (Ottawa: DND Canada, 19 July 2001), 14. Definition – *High-Fidelity* – Visual, auditory, and tactical cues emulate operation of the real aircraft, and aircraft systems and equipment to a very high degree. High-fidelity simulation systems are capable of all-aspect maneuvering and weapons employment. Training fidelity is compromised by the absence of physiological effects of G forces.

Figure 7 - Inside the CF-18 Multi-Task Trainer at DRDC Toronto

With a qualified project DRDC scientist (Dr. Grant), and two experienced Canadian CF-18 fighter pilots controlling the IOS station and acting as the White Force, the dialogue and communication with the CF-18 pilot in the simulator was quite successful. Throughout the exercise, close co-ordination and applicable scenario modifications and trigger events were discussed and actioned between DRDC and AFRL, Mesa staff. Scenarios for the mission included the Nellis and Iraq databases, which already existed, and were integrated for the crew with the existing Falconview flight planning tool (see figure 8).

Figure 8 – DRDC Toronto - Mission Planning Area; Falconview Flight Planning

The scenario plan involved a two-v-two (1-CF-18, 1-F-16 vs. 2-F-16), which was briefed and debriefed by the CF-18 pilot via video teleconferencing. For the briefing/ debriefing aspects between U.S. and Canada, things were kept simple with one slide on the SMARTBOARD depicting the overall tactical air picture. A video telecommunication link was provided to allow questions and dialogue amongst participants. Overall, the DMT sessions witnessed went very smoothly and were quite successful with all tasks and objectives completed effectively. A *strong cohesion and team atmosphere* was observed amongst all the geographically dispersed crews and white force personnel. Strengths for this DMT, long-haul, networked session included logistics, excellent cockpit and IOS communication amongst all players, strong *interoperability* (systems, procedures) demonstrated between U.S. and Canadian participants, sufficient air conditioning for MTT operation, and high-fidelity visual displays in the cockpit that were considered very good for Basic Fighter Maneuvers (BFM). Areas of interest highlighted by the participants included the pilot having a minor distraction in the cockpit because the displays did not extend all the way to the ground level on the sides of the cockpit, and that during the mission, pilots could not visually see the smoke from missiles launched.

This demonstration depicted provides Canada a strong foundation as the CF further embarks on this international, innovative approach in preparing combat crews for future coalition operations. Through these collaborative activities, DRDC and the CF have become more knowledgeable and experienced in evaluating the advantages and limitations of a DMT networked system.

ADVANTAGES OF DMT

From these trials, some key advantages have emerged for the fighter community that includes allowing inter-squadron, wing, joint and coalition training opportunities that would not otherwise be possible. DMT will allow all the players in the "kill chain" (find, fix, track, target, engage, assess) to work together, which is not now possible, even at Maple Flag and Red Flag. DMT could potentially allow mission rehearsal in the virtual, real environment with realistic threat scenarios. Overall, DMT can increase the efficiency and value of actual flying hours with crews being much better prepared for the flying mission at hand. DMT affords the possibility of pure tactical training of the highest caliber with practice of air-to-air and air-to-ground tactics and the handling of large force scenarios. The improved communication skills in a coalition environment and strong controller relationships in the scenarios will provide an increased sense of *trust* and confidence amongst the whole package. It was shown that the long-haul, networked simulation (data and communication) for coalition training has evolved considerably since its inception into a stable, and highly effective working environment.

One must not forget, given the limited flying hours already in place for the CF-18 community, that you cannot replace YFR with simulation. The DMT simulation will allow the CF to augment and enhance fighter pilot training and combat effectiveness.

DMT will help *bridge the gap, complementing, and offering an alternative* to legacy stand-alone simulation and live coalition exercises. With the inadequacies of the current simulators for combat ready crews and the limited availability of live training exercises such as Maple Flag and Red Flag, DMT can play a *pivotal role in the combat readiness* of our fighter crews for collective and demanding coalition missions.

CHALLENGES IN DISTRIBUTED SIMULATION

There are some areas of DMT that have current limitations and will require further study. One key area is establishing a technologically capable, *user-friendly*, *briefing/debriefing system* for geographically dispersed participants. The mission planning, briefing and replay/*feedback* are vital areas and key components in the DMT training process to ensure that effective and valuable training is accomplished. Although previous methods such as secure fax, cameras, and telephones can be used satisfactorily to a certain degree in the near term, the use of progressive technology such as video teleconferencing, SMARTBOARD, and whiteboard assets should continue to be pursued. The key is for DMT participants to be provided with effective familiarization training on the brief/debrief system and standard coalition procedures for use of the technology and its structured application in the brief/debrief system.

Another limitation and concern includes the amount of *co-ordination and white force personnel* required to run a DMT system. The co-ordination and magnitude of work for white force personnel include database and scenario development, and the interaction, telecommunication set-up for a long-haul network amongst remote sites. It is critical to have experienced, established personnel (i.e., sufficient manning outside CF regular force) overseeing a DMT system in order that continuity and progress in its operation is maintained. This will allow focused configuration control and system growth opportunities to remain *interoperable* with the United States and other coalition partners.

A key consideration and current limitation is *security* of the network and its databases. Several nations have had difficulties in the past establishing secure networks with their local service providers and DMT partners. In addition, the issue of multi-level security for coalition connectivity has been a highlighted concern. With time, it is hoped that the continued growth of technology, and coalition experience will resolve these critical aspects.

In concert with the security of the network is the DMT protocol.[49] Currently, DMT systems use Distributed Interactive Simulation (DIS) architecture. DIS provides a standard means for interconnecting simulators with a standard protocol but is limited when dealing with virtual and constructive simulation. With its high computational power requirement and its open, standard protocol, DIS has the disadvantage of having potential insecurities for allowing eavesdropping on exercises.[50] US DoD has stated that High Level Architecture (HLA) will be the replacement for DIS. HLA uses the concept of a federation, which is a collection of individual simulators (federates) linked together and distributed across large geographical distances.[51] HLA has the potential to be considerably more efficient than DIS as only the data required to support a federation is sent over the network rather than the redundant data sent in the DIS protocol. HLA will provide an automatic level of security with data broadcast being Federation specific. If interested in further technical details on DIS versus HLA architecture, refer to Annex C of this paper.

It has been noted that previous trials in the U.S., U.K. and Canada have primarily been engineering exercises looking at the feasibility of distributed simulation. Having proven now the feasibility of the DMT concept, some research has transitioned to a key concern and challenge related to behavioral issues, namely focusing on measuring the effectiveness of the training. The

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[49]Clark, Ryan and Zalcman, Advanced Distributed Simulation for the Australian Defence Force…, 72. Definition - *Protocol* – a set of rules governing a data communications procedure that must be followed to enable two or more computing devices to exchange and read instructions and messages.
[50]*Ibid*, 6.

primary purpose of *performance measurement* is to identify strengths and weaknesses in the knowledge and skills necessary for successful air combat so that training can be focused on addressing identified MEC deficiencies.

Assessment of trainee performance has been problematic in the past for many reasons. These include for example, the scenarios, which contain many different elements and encompass a wide variety of complexities. Variables used in creating scenarios include mission type (i.e., OCA, DCA), number of enemy aircraft, types of aircraft and ordnance, number of groups, group formations, maneuvers, and the level of enemy aggressiveness and reactivity.[52] The complexity of these scenarios can be rated via empirical scaling or through subject matter expert (SME) assessment.

As part of this standardized human performance assessment, an automated performance evaluation system could be used, which tracks extensive data on the DMT system. This type of evaluation system is more focused toward skills that have defined performance, such as formation positioning and successfully establishing the "notch"[53] in a defensive maneuver. For those skills that are not easily evaluated by automatic means, there are observation-based performance ratings. This will allow white force training personnel to decide where to focus an observer's attention. With SMEs providing key performance indicators (i.e., specific behaviour indicating readiness), one will be able to monitor observable behaviour that is linked to specific events and competencies.

Through AFRL research and initial studies from DRDC, *objective* simulation-based measures and *observation*-based measures *together* provide a rich basis for assessment of the knowledge and skills that support each MEC. By using a common measurement framework,

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[51] *Ibid*, 7.
[52] Herbert Bell, Peter Crane, and Robert Robbins, *Mission Complexity Scoring for Distributed Mission Training*, 4. Proceedings of the I/ITSEC 2001 Conference.

observation and simulation based data can be integrated to provide effective assessments and instructor feedback at the knowledge, skill and MEC level.[54] For further details on performance measurement, refer to Annex D of this paper.

Having considered the advantages and challenges that face DMT networked technology, we shift our attention chronologically to current DMT initiatives for coalition partners and Canada.

THE WAY AHEAD – CURRENT DMT INITIATIVES

PROGRESS OF DMT IN THE UNITED STATES

Since its concept development in 1997, DMT has evolved most significantly in the United States. Besides the DMT engineering development models located at AFRL, Mesa, the United States currently have F-15C mission training centers (MTC – see figure 9)[55] with distributed mission trainers located in Eglin AFB, Florida; Langley AFB, Virginia; and Elmendorf AFB, Alaska. There are also F-16 MTC's (see figure 10) located at Shaw AFB, North Carolina; Mt. Home AFB, Idaho; and AWACS MTC's at Tinker AFB and Elmendorf AFB, which all have the capability of networked simulation with one another.

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[53]NATO Brevity Words; available from http://www.kangaldogs.net/training/docs/nato.htm; Internet; accessed 04 April 2004. Definition – *Notch* – an all-aspect missile defensive maneuver to place threat radar missile near the BEAM.

[54]Thomas Carolan, Brian Schreiber, and Winston Bennett, *Interrelated Performance Measurement and Assessment in Distributed Mission Operations Environments: Relating Measures to Competencies,* 9. Proceedings of the I/ITSEC 2003 Conference.

[55]Mission Training Centers include items such as distributed networked simulators which provide high-fidelity simulation of the aircraft hardware, performance and capability, Instructor Operator Station/Mission Desk, Briefing/Debriefing System, aircraft weapon systems, threat, terrain and computer generated force databases, and a Mission Training Control System capable of managing the MTCs local and long-haul networking environment.

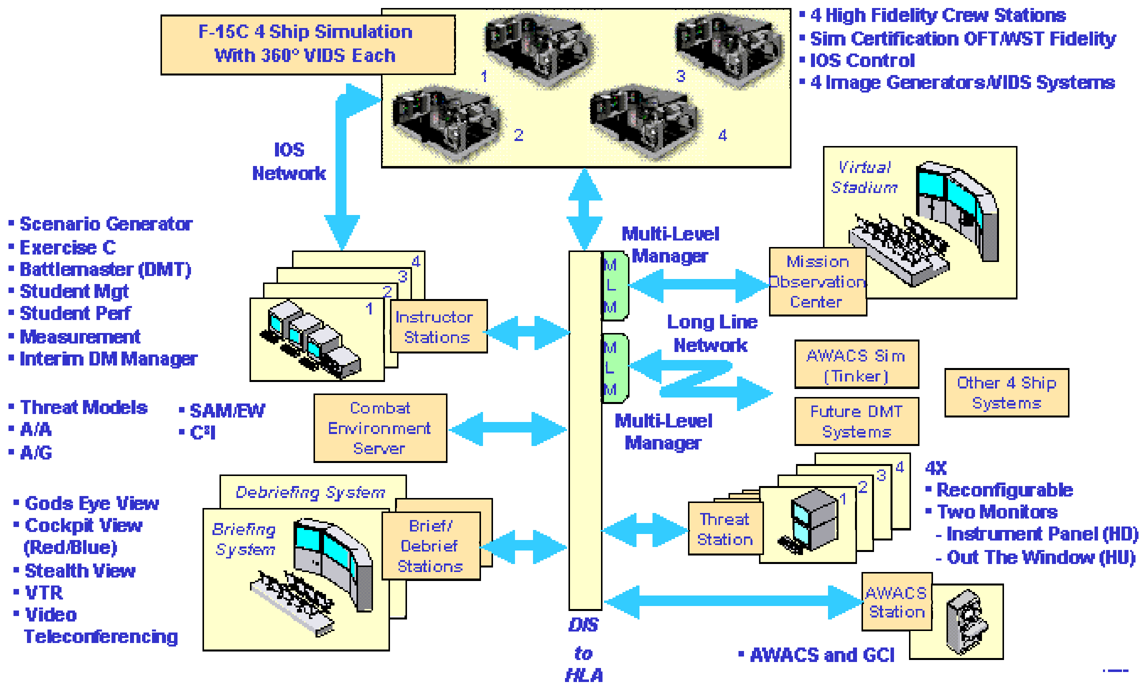

Figure 9 – F-15 Mission Training Center (includes networked integration with other remote DMT systems)

Figure 10 - Two of four F-16 Multi-Task Trainers and Mission Desk (IOS Station) at AFRL, Mesa, Arizona. Example of a Mission Training Center

NATO PERSPECTIVE

Now, how does NATO fit into this DMT technology capability? Air power needs to be flexible to allow NATO to react promptly to an escalation in a crisis situation. The balance between flying skills and weapon system operation is now evolving to place greater emphasis on sensor manipulation, information management, and situational awareness. This change generates a new training need for a complex tactical situation in which sensor and weapon systems can be employed in association with other aircraft. Such factors make modern air operations more reliant on such areas as SEAD, EW and the increased need for precision strike. As a result, NATO Air Doctrine is evolving towards more Composite Air Operations (COMAO) with multiple nations contributing a variety of different assets.[56] This requires nations to understand collective doctrine, tactics, planning and C3I.

With the lack of adequate range availability, the pressure to reduce training flying hours, and the limited opportunities to practice co-ordination of critical, multi-national, NATO air missions in a representative operational environment, one needs to find a solution to complement the current flying exercises. Currently, NATO training for Composite Air Operations takes place at Red Flag, Maple Flag, NATO Tactical Leadership Programme (TLP), which is conducted four times per year in Belgium, and the annual NATO Air Meet (NAM) exercise.

To provide some background, NATO commissioned a multi-national team study, titled Studies, Analysis and Simulation (SAS) 013 in August 1998, to assess the potential of advanced distributed simulation to complement live flying training in order to enhance NATO capability to conduct composite air operations. This included an examination of training needs, a review of NATO air training practices today, a discussion of the state of the art in distributed simulation technology, and an outline of a vision for the future. The study assumed that aircrew participating in mission training for composite air operations possess the basic individual and team skills needed to be categorized as combat ready. Such aircrew would then master the collective skills necessary in multi-national operations as part of a larger unit involving two or more teams from two or more countries.[57]

Note that for NATO, the concept discussed was given the term Mission Training via Distributed Simulation (MTDS) in order to distinguish it from various national initiatives, such as the U.S. DMT program.

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[56]Barry Tomlinson, *Aircrew Mission Training via Distributed Simulation – A Review of NATO Initiatives,* 4. Paper presented at the NATO Research and Technology Organization (RTO) Studies, Analysis, and Simulation Panel (SAS) Symposium, Brussels Belgium, 3-5 April 2002.
[57]*Ibid*, 4.

The findings of the SAS-013 study concluded in May 2000 that MTDS does offer great potential to enhance NATO's operational effectiveness in composite air operations and other kinds of air operations. A further finding is that live flying training has many constraints, and in isolation, cannot fully prepare NATO aircrew for future composite air operations. *MTDS (i.e., DMT) can begin to fill the training gap and should be used to complement live flying training.*[58]

To make progress with MTDS in NATO, a task group (SAS-034) was formed to develop and demonstrate distributed simulation (MTDS) concepts. This NATO group began operating in May 2001 and will continue for approximately three years with the following principal aims: to increase the awareness among the NATO military community of the potential of MTDS, to conduct a demonstration training exercise to show the potential benefits in NATO of multi-national mission training through distributed simulation, and to propose further actions needed to implement and exploit MTDS in NATO and the nations.[59] In accomplishing these aims, NATO is planning to carry out Exercise First Wave in the fall of 2004.

NATO - EXERCISE FIRST WAVE

Exercise First Wave (War Fighter Alliance in a Virtual Environment) is a joint project between the SAS Panel and the Modeling and Simulation Group (MSG) of the NATO Research and Technology Organization (RTO). First Wave will be the first ever multi-national wide area networked real-time simulation of COMAO in *NATO*. This synthetic COMAO environment will be capable of supporting both manned elements (virtual) and constructive elements (CGF) networked over a wide area network (WAN). This will involve approximately 15 simulation sites, which involve Canada, France, Germany, Italy, Netherlands, United Kingdom and the United States (see figure 11).

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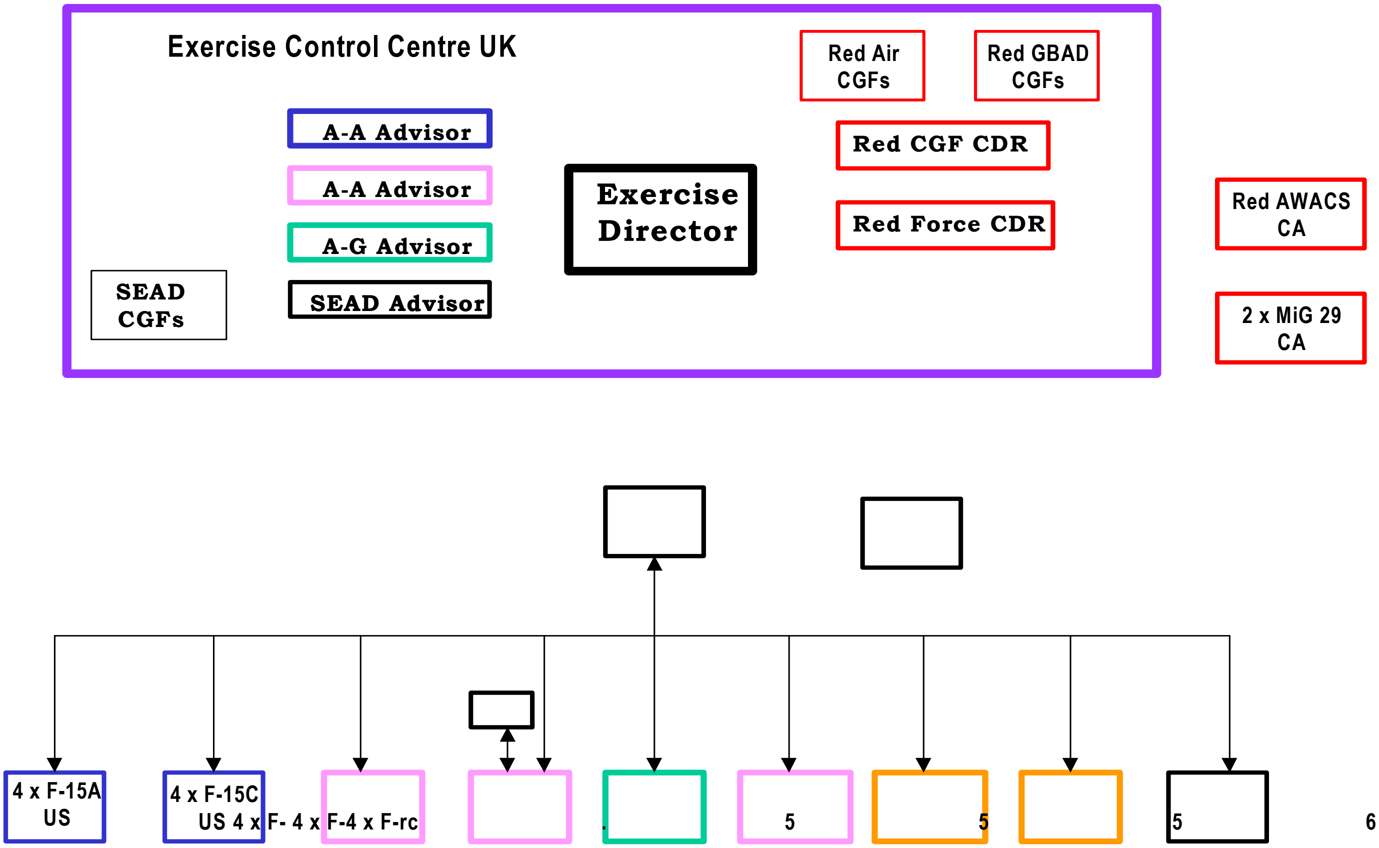
[58]Barry Tomlinson, "Aircrew Mission Training via Distributed Simulation – the Potential for NATO", *The Aeronautical Journal*, (March 2002), 158.
[59]Tomlinson, *Aircrew Mission Training via Distributed Simulation – A Review of NATO Initiatives*…, 10.



Exercise Control Centre UK
Red Air CGFs
Red GBAD CGFs
A-A Advisor
Red CGF CDR
A-A Advisor
Exercise Director
Red Force CDR
Red AWACS CA
A-G Advisor
SEAD CGFs
SEAD Advisor
2 x MiG 29 CA
4 x F-15A US
4 x F-15C US 4 x F- 4 x F-4 x F-rc
5
5
5
6

operations. The exercise has been designed to facilitate research in key areas including exercise management, *interoperability* and CGF issues.[61]

With aircrew already trained to combat ready status, the exercise will be using a Kosovo scenario with a real world database of the Adriatic region. The exercise scenario will assume approximately Day 30 of an "air campaign", at which point, it will be assumed that a degree of air superiority has been established.[62] With the exercise planned to last for four days, which includes familiarization training, the two main simulation missions will commence on the ground at several Italian east coast bases and consist of medium level laser-guided bomb (LGB) attack profiles against a range of fixed facilities in the first mission and mobile targets for the second mission with the target objective including a deployed SA-6 battalion. Emphasizing a complete mission cycle, under the leadership of a package commander, each formation will plan and brief their tasks, in co-ordination with other formations, fly their sorties and then conduct subsequent formation and mass debriefs.

Challenges for this exercise include the need for a real-time secure data network, and interoperability amongst the various countries' simulation and communication networks. One of the major concerns with the exercise is security. Security has both a technical and a policy aspect. Technical issues involve the development and supply of suitable encryption devices to match the modern, international communication methods. Policy issues are concerned with just what data each nation may be willing and prepared to release with respect to their own weapons systems and threats. Concerns also arise with respect to the accreditation process, which has to satisfy national authorities about the integrity of the network. Accreditation can be quite lengthy and extremely difficult to achieve.

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[60]Ebb Smith and Squadron Leader Bobby Anderson, *NATO SAS-034 Exercise First Wave User Requirements Document*, March 2002, 6.
[61]*Ibid*, 7.
[62]*Ibid*, 15.

This exercise does recognize that limited opportunities exist for NATO to conduct coalition live flying training exercises. First Wave will provide NATO experience in conducting multi-site exercise management of a distributed WAN simulation, addressing multi-national security processes, using the high level architecture (HLA) and the federation development process, sharing models and databases amongst coalition and industry partners, and validating and refining representative measures of effectiveness and performance for assessing MTDS.[63]

Exercise First Wave is a significant step in bringing together several coalition partners in a distributed network simulation environment with a key goal of improving *interoperability* amongst NATO members and better preparing crew and package readiness for future coalition operations.

CANADIAN ADVANCED SYNTHETIC ENVIRONMENT (CASE)

As part of Exercise First Wave, the Canadian Advanced Synthetic Environment (CASE) Project will provide the co-ordination of Canadian participation/networking with the NATO partners. For background on CASE project development, the Canadian air force currently has no co-ordinated capability to use modeling and simulation processes for requirements definition, doctrine/tactics development, test and evaluation or distributed training.[64] This deficiency was highlighted with the air force employing numerous types of simulators that were all "stove-piped." This meant that modeling resources were not sharable, joint training simulation was impossible, and the air force was unable to use simulation-based weapon system management practices. In accordance with Chief of the Air Staff Guidance, all new project flight simulators, operational mission simulators and flight training devices must have the capability to link with

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[63]Jan Van Geest, *First Wave - War Fighter Alliance in a Virtual Environment Brochure*, Issue 1, 25 April 2003.
[64]Department of National Defence, *Statement of Operational Requirement - Canadian Advanced Synthetic Environment* (Ottawa: DND Canada, September 2003), 1.

one another.[65] The simulation link capability could apply to aircraft such as the CF-18 Hornet, CP-140 Aurora, and CH-146 Griffon helicopter. The CASE project is to provide the modeling and simulation tools necessary to transform the air force via distributed means. The Chief of the Air Staff tasked the CASE project staff to provide a plan to strengthen air force modeling and simulation capabilities through a managed, common synthetic environment.

The vision for the synthetic environment encompasses a comprehensive infrastructure including crew/user interfaces, modeling support, scenario development and generation, telecommunications, and management.[66] The CASE project will not purchase full simulators, but rather CASE will provide staff assistance, common models and specifications for plugging into the synthetic environment. In June 2003, the CASE project, under NDHQ/Directorate of Aerospace Requirements (DAR) 7 leadership, started a three-year definition phase looking at three major areas to reduce the risk of a distributed synthetic environment. The three definition activities include the following:

a. management;

b. modeling; and

c. scenario development.

Typical *management* issues for synthetic environments include intellectual property, security, federation development, joint and combined agendas and international agreements. The CASE project will define management functions through the NATO Exercise First Wave. Canada will play a pivotal role in the development and execution of the September 2004 NATO "Kosovo" Mission Training via Distributed Simulation (MTDS) Exercise First Wave. With the co-operation of the DND Information Management (IM) group, CF simulators across Canada,

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[65]Department of National Defence, *CAS/DGAEPM Presentation - Canadian Advanced Synthetic Environment (*Ottawa: DND Canada, January 2003).
[66]*Ibid*

with CF industry partners, will link and take full part in the exercise. Simulator assets, and units providing liaison personnel currently include the following: 42 Radar Cold Lake (C2 of red air defence), 1 CAD Winnipeg (Red Air Director), DRDC Toronto (two ship – CF-18 manned simulators), Bagotville (one CF-18 manned simulator), Mirabel (one CF-18 manned simulator), CAE Montreal (two MIG-29 red air manned simulators), and an NDHQ liaison officer at the Distributed Mission Operations Center (DMOC) at Kirtland AFB, Albuquerque, New Mexico. This exercise is aimed to provide comprehensive training for team-based and inter-team activities and provide lessons learned for MTDS and its management concerns.

M*odeling* definition activities will focus on the "Griffon Mothership" initiative. This modeling aspect determines how distributed entities, including legacy models and simulators, can plug into the CASE network. For this initiative, the CASE project has accepted responsibility for four highly functional, low-fidelity, no motion, Networked Tactical Simulators (NTS), following the successful conclusion of DRDC's Tactical Aviation Mission System Simulation (TAMSS) demonstration project.[67] To help define a modeling construct, the CASE project will network NTS assets from Gagetown (2), Carleton University, Ottawa (1), and X-Wave Company, Ottawa (1) to further explore long-haul networks. A key part of this modeling construct is several visual terrain databases (i.e., Gagetown and Kosovo area) that have been created by DND Mapping and Charting Establishment (MCE) in Ottawa. The modeling construct includes dedicating one source/organization within DND for databases. For example, if DND has validated currently existing weapons fly-out models and terrain databases, this could potentially allow reduced acquisition time for simulator projects and allow the simulators to remain up to date at the operational units with model/database updates being provided directly on-line. The ultimate aim is to have the first DND wide area network for simulation-based acquisition. This includes, as a milestone set for December 2004, setting up a long-haul network with the standardized visual terrain database from MCE with the four Griffon TAMSS simulators linked with United States Army Air Cavalry simulator assets at Fort Rucker, Alabama.[68]

Scenario development is the third area of the CASE project definition phase. As on-going Exercise First Wave development has demonstrated, complex scenarios demand considerable workload and time. This scenario development research area will involve a synthetic mission called "War in A Box," currently planned for execution in 2005. It will be a large-scale, *joint virtual exercise* with primary support being given from the Army Simulation Center in Kingston and naval support from the Maritime Warfare Center (MWC) in Halifax.[69] This exercise is currently planned as a Non-Combatant Evacuation Operation (NEO) from a war torn African country. The air force could include CC-130 Hercules simulation assets for this exercise.

The overall long-term joint vision of CASE is to have a portal entry at every Canadian Forces operational base, allowing a plug and play type of availability in simulation. CASE's *innovative* and overall co-ordinated approach will prove instrumental to upcoming simulation projects such as the CF-18 Advanced Distributed Combat Training System (ADCTS).

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[67]Lieutenant-Colonel Rick Thompson, Directorate of Aerospace Requirements (DAR) 7, e-mail received by author, 23 March 2004.

[68]Lieutenant-Colonel Rick Thompson, Directorate of Aerospace Requirements (DAR) 7, e-mail received by author, 23 March 2004. Note: Fort Rucker is the main base for U.S. army aviation flight training and the location of the U.S. Army Air Maneuver Battle Laboratory.

[69]*Ibid*

CF-18 ADVANCED DISTRIBUTED COMBAT TRAINING SYSTEM (ADCTS)

The CF-18 ADCTS consists of a distributed network simulation and is an integral part of the CF-18 omnibus Incremental Modernization Project (IMP) that was initially approved in July 1998. A shift of emphasis has occurred in the Canadian fighter force where mission effectiveness in combat has become more a function of tactical employment of a weapons system than skilful handling of an aircraft. With the legacy training facilities that exist, there lies a significant training gap for our fighter force.[70]

Due to high costs, safety factors, mission complexity, airspace and range restrictions, weather, aircraft fatigue, reduced flying hour allocations and real-world commitments, Canadian aircrew are restricted in their ability to effectively train across the spectrum of core activities. The yearly flying rate has reduced to only 182.7 flying hours for baseline capable operational squadron pilots. This reduction is largely due to aircraft fatigue life concerns and the high operating cost for the CF-18 of $19,230 Canadian dollars (BY 2003/2004) per hour.[71] The CF-18 community must rely on simulation to *complement* the limited, but critical, flying opportunities available.

However, the currently existing CF-18 Weapon Systems Trainer (WST) at Cold Lake and the CF-18 Operational Flight Tactics Trainers (OFTTs) at Bagotville and the Mirabel contractor facility are outdated and <u>do not</u> provide the capability to train as a multi-ship formation, produce tactical Precision Guided Munitions (PGM) employment scenarios, train full mission profiles against sophisticated interactive threats, or match the planned technical configuration of the modernized CF-18 with the IMP project.[72]

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[70]Department of National Defence, *Statement of Operational Requirement - CF-18 Advanced Distributed Combat Training System (ADCTS) project 00000113…*, 1.3.1, 24.
[71]Keith Hunt, Directorate of Aerospace Requirements (DAR) 5 Project Support Specialist, e-mail received by author, 09 February 2004.
[72]Department of National Defence, *Statement of Operational Requirement - CF-18 Advanced Distributed Combat Training System (ADCTS) project 00000113…*, 1.3.1, 24.

The operational requirement for the procurement of a new CF-18 simulation system is based on three critical aspects, which include the following:

a. Constraints to Training. Critical issues include the significant reduction in YFR to extend the expected life of the aircraft, and the economic and environmental concerns with respect to the availability and usage of training areas;

b. Legacy System Obsolescence. The current CF-18 WST and OFTT simulators are outdated and their limited operational capability is threatened by component obsolescence; and

c. *Distributed Mission Training.* Team training is an essential element of CF-18 operations. To allow future joint and combined training opportunities, the simulation system must provide connectivity among training devices that allows training across the entire spectrum of flight missions and tasks. The evolution of Advanced Distributed Mission Simulation (ADMS) has matured to the point where it is capable of providing a foundation for new dynamic interactive training systems that will improve significantly, the fighter force capability to train the way we fight.[73]

With the use of commercial off-the-shelf (COTS) equipment, the ADCTS shall emulate CF-18 post-IMP phase I performance and characteristics which will utilize the SMART concept which incorporates the use of simulation and modeling technology for the purposes of Acquisition, Rehearsal and Training (SMART). ADCTS will provide the ability to conduct the following:

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[73] *Ibid*, 1.1.2, 20.

a. realistic joint and combined team training;

b. system testing such as hardware-in-the-loop missile or EW trials;

c. simulated and emulated software upgrades to the aircraft, systems or weapons;

d. operational analysis such as the impact of ROE; and

e. joint and combined mission rehearsal.[74]

The ADCTS shall provide realistic training to support anticipated real world *coalition* operations, and includes the following roles:

a. NORAD air defence and sovereignty operations;

b. NATO air-to-air and air-to-ground operations;

c. Fighter operations against land or maritime threats to Canada; and

d. Air-to-air and air-to-ground contingency operations anywhere in the world.[75]

The ADCTS goes far beyond replacement of the aging CF-18 legacy simulators. The result will be a multi-level synthetic battlespace that *supports realistic joint and combined training in near real time.* A key interoperability aspect is that the system architecture will conform to the U.S. Defense Modeling and Simulation Organization (D cen-2.leling and 9i

active and passive sensors such as radar (all modes), identification friend or foe (IFF), forward looking infra-red (FLIR), radar warning receiver (RWR), electronic counter-counter measures (ECCM), night vision goggles (NVG), air-to-air weapons, and conventional and PGM air-to-surface weapons.[79]

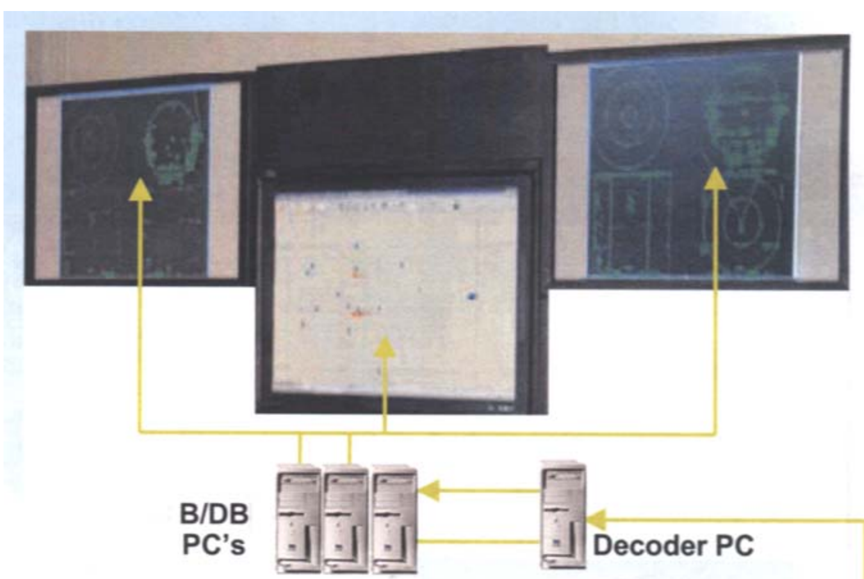
Other elements of the CF-18 MTC include the following:

a. synthetic environment;

b. DMT databases with applicable database development tools;

c. mission control centers which consist of viewing monitors, instructor operator stations (IOS) and distributed mission training control system capable of managing the CF-18 MTC local and long-haul networking environment; and

d. briefing/debriefing stations (see figure 13 - includes mission planning stations, video teleconferencing, SMARTBOARD, applicable telecommunications).[80]



author, 09 February 2004.

[79]Department of National Defence, *Technical Statement of Requirement - CF-18 Advanced Distributed Combat Training System (ADCTS)…,* 3.2.6.11.2, 23.

Figure 13 – ADCTS Project – Initial Design of Brief/Debrief Stations

[80] *Ibid*, 3.1.3.2, 8.

This system will provide pilots with a "seat of the pants"[81] simulator visual system of +/-180 degree horizontal and +90/-45 degree vertical, which will accurately model real world threats and a visual database to conduct fighter training from 100 feet above ground level (AGL) to 50,000 feet AGL (see figure 14).[82]

Figure 14 - ADCTS Project – Air Combat Emulator

The CF-18 MTC and ACEs will enable CF-18 crews to simultaneously engage in any combination of the following modes of training: stand alone, locally networked simulation, long-haul networked simulation (see figure 15), and networked combined live/simulated mode with

[81]*Ibid*, 3.2.6.10.2.1.1, 20. Definition - *Seat of the Pants* – shall simulate the force and acceleration environment of the CF-18.
[82]Department of National Defence, *Statement of Operational Requirement - CF-18 Advanced Distributed Combat Training System (ADCTS) project 00000113*…, 9.5, 55.

the Cold Lake Air Combat Maneuvering Instrumentation (ACMI) real time monitoring system.[83] These capabilities are not possible with the current obsolete simulation equipment.

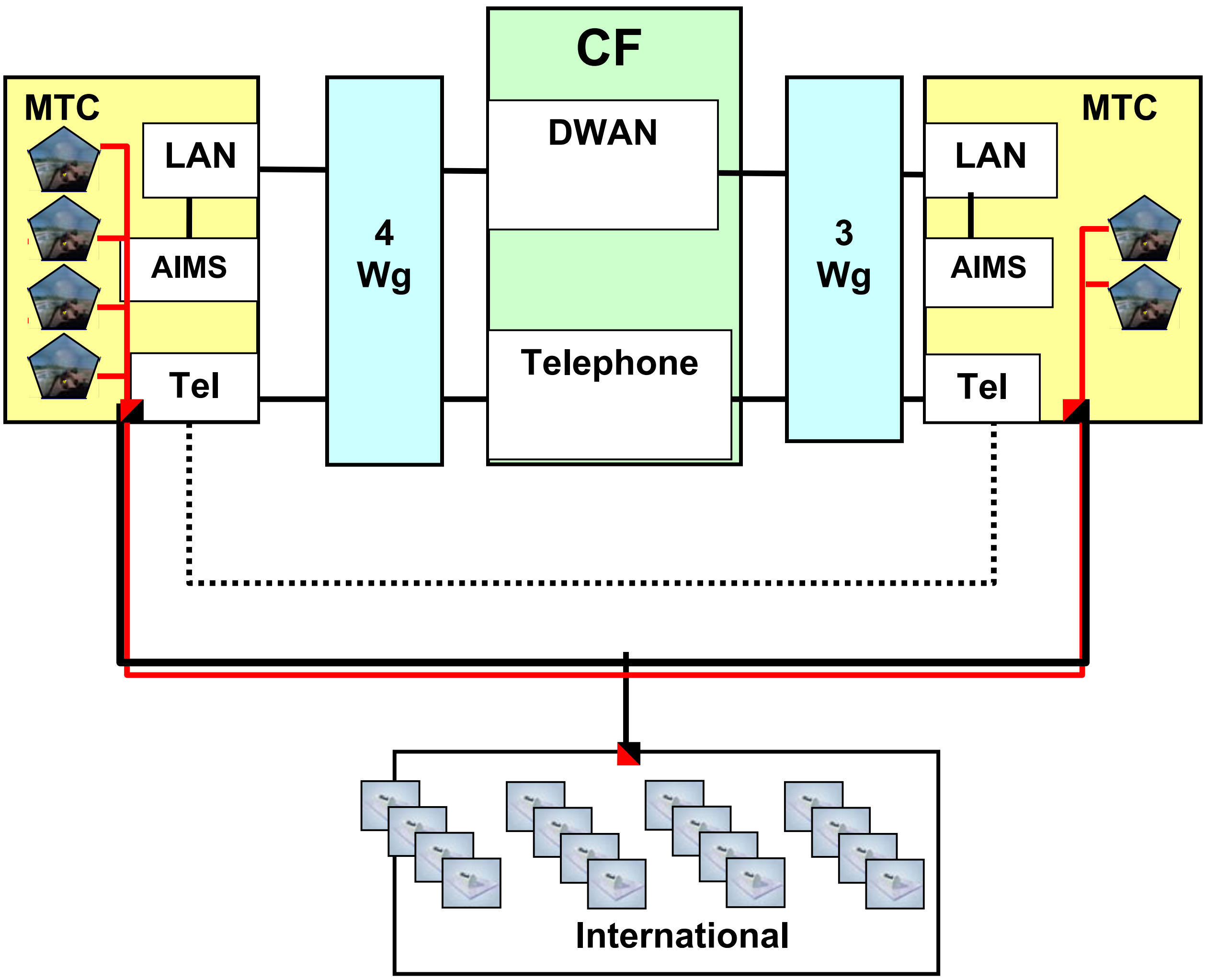


Figure 15 - ADCTS Project - DMT and Long-Haul Network Architecture

With the ADCTS contract awarded in March 2004 and delivery anticipated following 18 to 28 months timeframe, the envisioned plan is that DND will own all the equipment and MTC

[83]Department of National Defence, *Technical Statement of Requirement - CF-18 Advanced Distributed Combat*

facilities. Like the USAF F-15 and F-16 MTC facilities, a contractor will be paid to operate the MTC. Contractor support will prove critical for continuity in exercise management and database development. Contractors operating the MTC will allow the current regular force fighter pilot cadre to concentrate on training of advanced skills for combat ready pilots to prepare for effective employment in future coalition operations. To offset the magnitude of work for the instructor cadre, the contractor is currently planned to provide the following:

a. Category 1 Instructor. This contracted instructor will be an IOS operator/mission facilitator only who will be used for all multi-ship networked missions;

b. Category 2 Instructor. This contracted flying instructor (non CF-18 background) will be capable of providing briefings, direct the conduct of the mission, and debriefings/assessments of non-tactical single-ship sorties such as Instrument Flying, Navigation Training, and Night Vision Goggle Training; and

c. Category 3 Instructor. This contracted, civilian F-18 instructor will be capable of briefing, conducting, de-briefing and assessing single or multi-ship tactical sorties.[84]

Training System (ADCTS)…, 3.2.2.4, 10.

[84]Keith Hunt, Directorate of Aerospace Requirements (DAR) 5 Project Support Specialist, e-mail received by author, 09 February 2004.

PART-TASK TRAINERS (PTTs)

As part of the CF-18 air combat training system, Part-Task Trainers (PTTs) will form part of the building block approach. PTTs are non-DMT networked desktop PC computers, stand-alone units[85] utilized for training hands on throttle and stick (HOTAS) switchology/dexterity and techniques for aircraft and weapons systems employment and tasks. Some of the tasks that will be practiced include air intercept training, air combat maneuvering, conventional and precision weapon delivery, air-to-surface tactics, EW, mission review and editing, and mission rehearsal.[86] With the exception of the high fidelity displays, control stick, throttles, and HOTAS switches, all non-mission oriented cockpit symbology and switches will be graphically emulated and manipulated via a mouse and a medium-fidelity visual depiction will be shown on the PC display (see figure 16). Some key aspects that link with the MTC facility include Wing secure network sharing for mission planning, scenarios and file transfer. Overall, the pilot will have the capability to conduct a passive mission walk-through, a training mission, or active mission rehearsal based on the Portable Flight Planning System (PFPS) planned mission.[87] The plan is to allow for future growth and the potential for future networked simulation with the MTC.

[85]*Ibid*. Part-Task Trainers are network capable if the CF chooses to do so in future.
[86]Department of National Defence, *Statement of Operational Requirement - CF-18 Advanced Distributed Combat Training System (ADCTS) project 00000113*…, 4.3.1.3, 43.
[87]Department of National Defence, *Technical Statement of Requirement - CF-18 Advanced Distributed Combat Training System (ADCTS)*…, 3.3.3.19.4.1, 71.

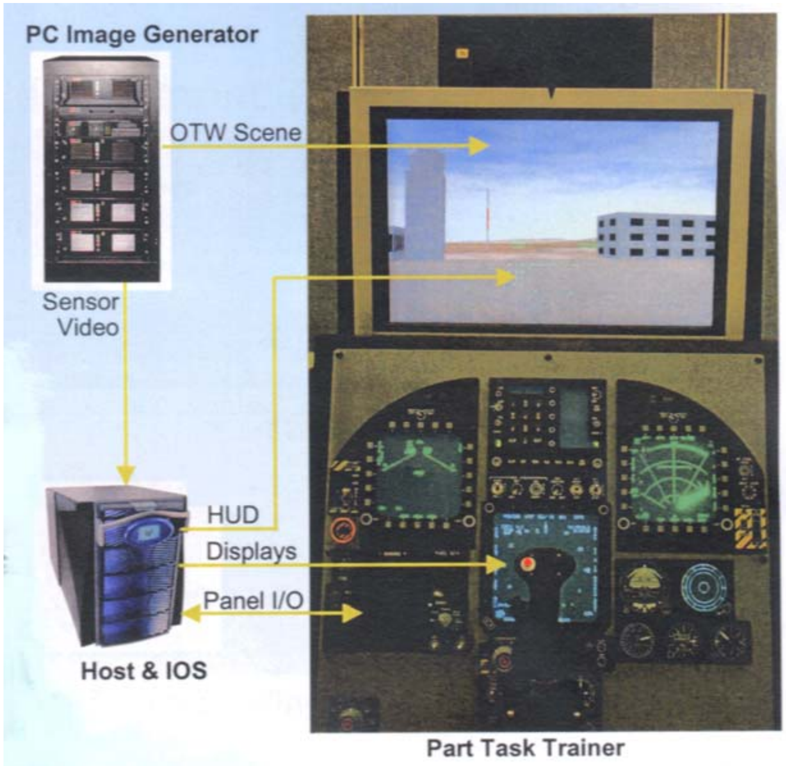


Figure 16 - ADCTS Project – Part-Task Trainer (PTT)

ADCTS – PROGRESS IN CAPABILITY

To note, a training needs analysis (TNA) for the ADCTS project was completed in January 2000, which determined that future air combat training using ADCTS, in conjunction with aircraft training, has the potential to be 42% more cost effective than the legacy system.[88] As part of the current Training Development Integrated Product Team (TD IPT), ADCTS project staff will look at determining the training program for future initial and combat ready fighter pilots. An example of additional ADCTS training capabilities include one ACE that is re-configurable to a rear-seat configuration that will be networked with the front seat of another

[88]Department of National Defence, *Statement of Operational Requirement - CF-18 Advanced Distributed Combat Training System (ADCTS) project 00000113…,* 1.2.4, 3.

ACE to operate as one CF-18B (dual) aircraft.[89] This will enable the conduct of all elements of CF-18 training including Instructor Pilot Upgrade Training (IPUG).[90] In addition, the Fighter Weapons Instructor Course (FWIC) held at Cold Lake is being studied for DMT application. Currently, the FWIC course uses 92.7 flying hours (including support hours) and zero simulator hours due to its current CF-18 stand-alone simulation structure. It is suggested that ADCTS could potentially be incorporated into the FWIC course resulting in 72.3 flying hours and 24.0 emulation (i.e., ACE) hours.[91]

For deployment, two of the ACE simulators are planned to be transportable by land, sea or air transport (i.e., CC-130 Hercules). As per the Technical Statement of Operational Requirements (TSOR), the ACE can be transported anywhere in the world and functioning in a DMT environment within 14 days of notice to move, well within the 21 day combat readiness posture.[92]

ADCTS overall shall provide a system that allows CF-18 pilots to train for combat in teams and effectively prepare them for future *coalition* operations. With the "train-as-you-fight" doctrine, synthetic training will provide measurable cost savings and skill transfer benefit.[93]

<u>FUTURE DMT CAPABILITIES</u>

As just shown, DMT is becoming a reality for the CF in the near term. Previous DMT trials have successfully concentrated on and developed a stable, long-haul network between established military sites and carried out realistic and comprehensive scenarios in a synthetic

[89]Keith Hunt, Directorate of Aerospace Requirements (DAR) 5 Project Support Specialist, e-mail received by author, 31 March 2004.
[90]Department of National Defence, *Technical Statement of Requirement - CF-18 Advanced Distributed Combat Training System (ADCTS)…*, 3.2.6.7, 16.
[91]Keith Hunt, Directorate of Aerospace Requirements (DAR) 5 Project Support Specialist, e-mail received by author, 09 February 2004.
[92]Department of National Defence, *Technical Statement of Requirement, CF-18 Advanced Distributed Combat Training System (ADCTS)…*, 3.2.16.2, 55.
[93]Department of National Defence, *Statement of Operational Requirement - CF-18 Advanced Distributed Combat Training System (ADCTS) project 00000113…*, 3.1.3, 37.

battlespace based on a coalition environment. Now, to continue studies on the DMT synthetic training environment, one must consider any further DMT requirements required from the customer (i.e., the air force) in ensuring combat crew readiness for future operations.

One aspect that has been briefly mentioned is *mission rehearsal*. Mission rehearsal has been significantly lacking in the past in preparing our combat ready crews. Mission rehearsal can be defined as "practicing planned tasks and functions critical to mission success using a true-to-life, interactive representation of the predicted operating environment."[94] The scientific and air force training community believe that if specific missions can be practiced via simulation prior to actual flying, this form of mission rehearsal can provide more training value and potentially a higher operational readiness and greater confidence to the crews. Overall, air force personnel can receive more value out of each flying hour with the outcome being a higher caliber of crew performance.

With networked simulation, comprehensive scenarios can be developed by exercise management staff, mission scenarios can be rehearsed in their networked simulator with the normal package complement, and then the mission flown in the aircraft to solidify such areas as team skills, weapons employment, situational awareness and communication/coordination. DMT will provide a significant capability enhancement in comparison to the legacy, stand-alone simulators, which primarily focused only on abnormal and emergency procedures.

DMT can also provide benefit across the spectrum of CF-18 crew training. While on course at the operational training unit, instructor staff can validate a student's training in a multi-ship formation prior to going flying. At the operational squadrons, continuation training can allow simulation rehearsal of the various roles, practicing basic fighter maneuvers (BFM)[95] and

[94]Clark, Ryan and Zalcman, *Advanced Distributed Simulation for the Australian Defence Force*…, 71.
[95]Department of National Defence, *Statement of Operational Requirement - CF-18 Advanced Distributed Combat Training System (ADCTS) project 00000113*…, 13.

also scenarios involving North American Air Defence (NORAD) and the Operation Noble Eagle mission. Simulation rehearsals can also be used in preparation leading up to a pilot's combat ready status and lead upgrade training. Even before any Cold Lake ACMI range activity or Maple Flag /Red Flag exercise missions with all the key components of a large *coalition* package is conducted, one can practice the missions in the controlled, networked simulation environment.

DMT has excellent potential, however, training staff must be aware of some limitations when comparing mission rehearsal simulation to actual airborne missions. These include the following:

a. degree of accuracy for real world threat emulations;

b. visual acuity differences;

c. issue of target contrast in a visual arena;

d. weather effects;

e. lack of motion;

f. lack of G force; and

g. potential differences in cockpit configuration.[96]

On a *deployed operation, w*hen receiving the ATO, the crews could practice their mission to allow a smoother transition in the cockpit and improved co-ordination with other coalition assets and personnel. *Mission rehearsal while deployed* would be a valuable training mechanism for a coalition force. As stated in the DPG, as part of the Vanguard, 12 CF-18 and the associated crew have a global readiness posture of 21 days with a required sustainability of 180 days (6 months) for Operations Other than War (OOTW) and 60 days for combat operations.[97]

Definition -*Basic Fighter Maneuvers* – Also described as close in combat, this training encompasses those maneuvers required to engage, destroy, and/or defend against other aircraft in a visual arena.

[96]Todd Denning, Jeffrey Bell and Winston Bennett, *Tactics Development and Training Program Validation in Distributed Mission Training*, 8. Proceedings of the I/ITSEC 2003 Conference.

[97]Department of National Defence, *Chief of the Air Staff Planning Guidance 2003* (Ottawa: DND Canada, 2003), 2-2/25.

As seen by the 1999 *Kosovo campaign* involving CF-18 aircraft and crew and their multi-role capability, there were concerns with respect to pilot experience levels in a coalition setting and crew skills maintenance while deployed. As early as 1997/98, six CF-18's were primarily employed in the DCA role of CAP flying approximately 120 sorties over the Adriatic and Balkans area. In March 1999, Operation Echo/Allied Force marked the commencement of hostilities and the transition from peacetime to a wartime footing. This placed Canadian Task Force Aviano in a challenging situation as they were transitioning from 3 Wing Bagotville to 4 Wing Cold Lake personnel, combined with the government's decision to increase the number of CF-18's to 12 and then 18 aircraft. The learning curve was very steep for the expanding number of crews (32 pilots for 18 CF-18's) as they transitioned from CAP to air-to-ground Battlefield Air Interdiction (BAI) and Close Air Support (CAS) roles.[98] Through the professionalism, *training*, discipline and solid leadership, the CF-18 crews were successful in carrying out 678 combat sorties over nearly 2600 flying hours. Much of the time, a CF-18 four-ship formed part, and for a greater portion, *led a much larger strike package of NATO coalition aircraft* delivering laser-guided precision guided munitions onto the designated targets.

It must be noted though that throughout the 78-day campaign from March to June 1999, personnel and equipment were both stretched to the limit. Given the policy of holding a pilot in combat no longer than sixty days without a break, the CF had committed the available pool of combat ready pilots to the limit. The strong Canadian contribution to the coalition effort was an affirmation of the training (Maple Flag, Red Flag) and resources (i.e., increased flying hours) spent in previous years when the fighter force was more robust. A key issue though was " the varying performance level of the pilots involved. There was a vast difference in the experience

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[98]Lieutenant-Colonel David Bashow, Colonel Dwight Davies, and Colonel Andre Viens, "Mission Ready: Canada's Role in the Kosovo Air Campaign," *Canadian Military Journal* (Spring 2000): 59.

levels, and it is safe to say that the more senior aviators very much carried the younger ones."[99]

Some of the highlighted concerns of the Kosovo campaign included the following:

a. shortfall in weapons delivery training which would require more realistic simulators;

b. lack of i*nteroperability* with coalition partners (personnel and equipment);

c. difficulty sustaining aircrew training currency while *deployed*;

d. lack of in-theatre training for recently acquired capabilities; and

e. lack of *mission rehearsal capability*.

Deployability of simulator assets is a highlighted area of interest. It was demonstrated recently at an I/ITSEC conference in Florida that F-16 Multi-Task Trainers (MTTs) could be deployed, in a limited sense, via CC-130 Hercules, for a distributed network simulation mission. The set-up at the Florida conference was done within one day of arrival providing a limited visual system and no IOS station. There are, however, on going concerns regarding the deployability of distributed mission trainers that need to be addressed in future studies. These include key areas such as security of databases, international telecommunication access, night vision capability, and ability to link with databases such as terrain and CGFs. Of note, DRDC Toronto has commenced a Technology Demonstration Project (TDP) in April 2004 known as Advanced Deployable Day/Night Simulation (ADDNS). Anticipating the need for deployable simulations with night vision capabilities, the long term purpose of the DRDC led project is to allow the CF to rehearse with allies in synthetic environments prior to combat.[100]

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[99]*Ibid*, 56-57.

[100]Defence Research and Development Canada, *Distributed Mission Training Projects Brochure*, Fact Sheet no. T-06, March 2004.

As one can imagine, in this era of limited resources and low YFR, the challenge is to employ all means of training, including simulators and synthetic trainers to maximum benefit.[101] This is where DMT and mission rehearsal can play a pivotal role preparing the combat ready crews for conflict in a coalition environment.

A recent example can be shown where networked simulation prepared U.S. and U.K. war fighters for combat coalition operations. F-15C and F-16 MTC's were used as a training ground for Operation Iraqi Freedom in 2003. An Air National Guard pilot summed up his experience by saying:

> "I was downtown Baghdad at the start of tonight's activity and got to launch the first HARM missile of Operation Iraqi Freedom…The location of my flight and the tactics employed were exactly like we were practicing in the F-16 MTC at Shaw AFB before we left…talk about *Mission Rehearsal*!"[102]

Deployability and DMT mission rehearsal simulation will increasingly become a key ingredient for success in a coalition-tasked mission. As DMT network technology expands even further, the potential for conducting simulated joint force operations is within reach.

DISTRIBUTED MISSION OPERATIONS (DMO)

In the United States, Distributed Mission Operations (DMO) is the future organizational structure that will build on established DMT principles and broadens the scope and capability. DMO, formerly known as DMT, has been renamed in response to the vision of General Jumper, the U.S. Chief of Staff of the Air Force, to use this virtual kill chain to prepare U.S. and *coalition* military personnel for global operations. [103] The overall vision for DMO is to enable war fighters to train, *mission rehearse*, and operate in large Composite/Joint/Combined Force packages in a distributed full-spectrum battlespace. DMO will range from individual to full

[101]Bashow, Davies, and Viens, *Mission Ready: Canada's Role in the Kosovo Air Campaign…*, 61.
[102]*New DMO*, The Journal (December 2003); available from http://tspg.wpafb.af.mil/journal/newdmo.htm; Internet; accessed 09 March 2004.

mission rehearsal and will include live, virtual, man-in-the-loop, constructed and computer generated simulations. Under this DMO concept, a network of aircraft simulates air operations in conjunction with *command and control* units. As described by USAF General Seip, Air Force Deputy Director for Operations and Training, “It’s the next generation of *joint readiness training*.”[104]

At Kirtland AFB in New Mexico, the Theatre Aerospace Command and Control Simulation Facility (TACCSF) will play a pivotal role in the experimentation and Operational Test and Evaluation (OT&E) of the DMO system. The concept is designed to provide a ready, trained and rehearsed fighting force, *plus a means to certify component commanders and staff.* It will provide the decision-quality information necessary to build information superiority and predictive battlespace awareness for the Joint Force Component Commander such as the Joint Force Air Component Commander (JFACC).[105] DMO air, such as fighter cockpit linked simulators, is only a part of a larger DMO concept where *mission rehearsal* for theatre wide employment will be the primary focus (see figure 17 – training hierarchical approach). In the United States, the goal of the DMO implementation roadmap is to achieve a robust mission environment by 2010. The plan is for Mission Training Centers (MTCs), as discussed earlier in the paper, to be located at operational bases with elements including the following:

a. a fighter and air battle management MTC, comprising F-15, F-16, AWACS and special operations forces;

b. an integrated Intelligence, Surveillance, and Reconnaissance (ISR) center that will link JSTARS, Rivet Joint and the predator UAV;

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[103]*Ibid*

[104]Susan Rietze, “Distributed Mission Operations Shape USAF Training Projects,” *National Defense*, Vol 88, Issue 600 (November 2003): 72.

[105]*Air Force Distributed Mission Operations*; available from www2.afams.af.mil/programs/projects/afdmo.htm; Defence Internet (DIN); accessed 19 January 2004.

c. a command and control and space mission rehearsal MTC that will include the F-22 Raptor, F-15E and the B-2 bomber; and

d. a U.S. Joint National Training Capability (JNTC) for joint and coalition training.[106]

The USAF envisions DMO as a complementary capability to conduct large force training with substantially less impact to logistics, environment, and war fighting resources. The ability to train at this level on a regular basis holds the promise to expand combatant performance on many levels.[107]

As one can see, the advanced capabilities of DMT technology have a wide application for the future with respect to air force, joint and combined operations.

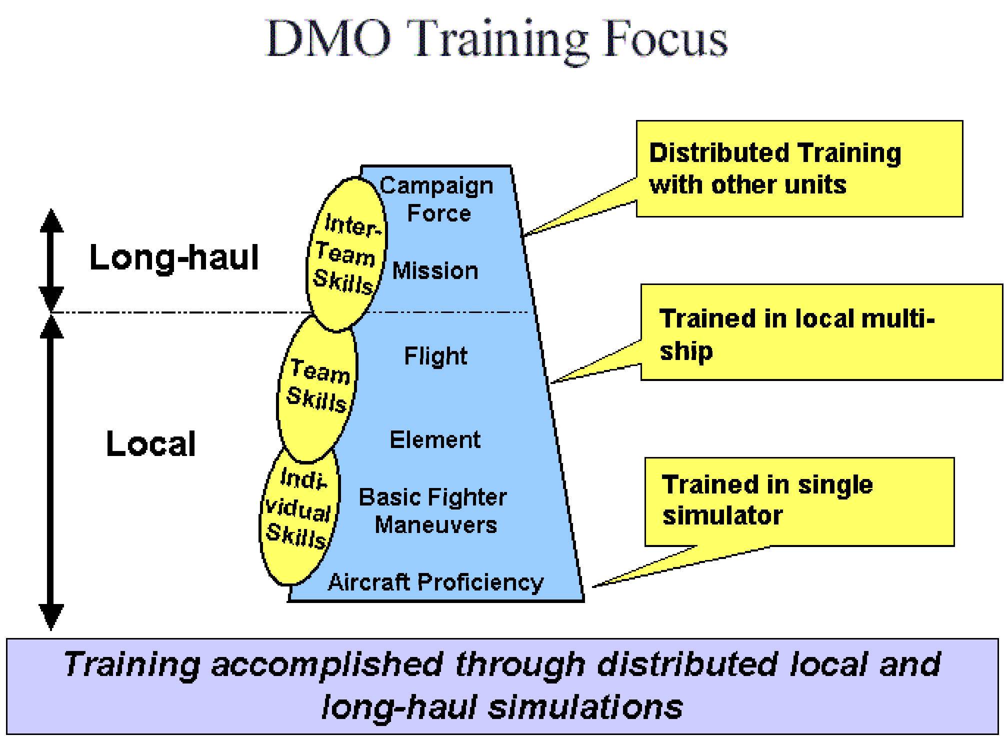

Figure 17 - Distributed Mission Operations (DMO) Focus

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[106]Rietze, *Distributed Mission Operations Shape USAF Training Projects…*, 72.

SUMMARY

The training of our CF fighter pilots has relied in the past on stand-alone simulator systems and in-flight training to teach the flying skills and techniques/procedures necessary for combat crew readiness. With no networked capability and reduced functionality/fidelity, stand-alone simulators have primarily emphasized abnormal/emergency procedures, thus providing only a limited, overall potential in preparing combat ready crews for future coalition/COMAO operations.

Operational and large-scale exercises such as Red Flag and Maple Flag have provided key opportunities to train crews in team and inter-team skills. Although significant benefits are gained by crews participating in Flag exercises, limitations such as range site capabilities, weather, and frequency of the events (i.e., attributed to cost/workload), make this only a partial solution to crew readiness training. There currently exists a *significant training gap* between the stand-alone simulators and the live flying training exercises for the CF-18 combat crews.

As demonstrated by the CF-18 involvement in the 1999 Kosovo campaign, the CF and its fighter force can be called upon by the Canadian government to participate in a wide variety of coalition operations. With the high CF-18 aircraft operating costs, and aircraft fatigue life concerns highlighted in today's fiscal climate, the CF, in keeping with the strategy 2020 concept, need to be innovative and find *alternative methods to complement* in-flight training in order to fully prepare our combat ready crews for effective employment in coalition operations.

Distributed Mission Training (DMT) is the innovative approach required for fulfilling this crew readiness training gap and can fully *complement* the existing flying hours and live flying exercises allocated to our combat crews. DMT can provide the increased training

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[107]Denning, Bell, and Bennett, *Tactics Development and Training Program Validation in Distributed Mission*

frequency and the flexibility in training scenarios/databases necessary for preparing combat crews in a coalition setting. DMT allows multiple players at multiple sites to engage in training scenarios in a synthetic environment ranging from individual and team participation to full theatre-level battles. In addition, DMT can complement the currently existing aircraft formation-training curriculum, including helping to prepare crews for combat ready status, fighter lead upgrade training, and fighter weapons instructor course (FWIC) objectives.

Distributed network technology has evolved and matured significantly since the USAF concept development in 1997. Through numerous trials and demonstrations, consistent positive results and strong progress clearly indicate that DMT is ready to fill this training gap. Advantages such as increased value and efficiency of actual flying hours, improved communication skills in a coalition environment and increased sense of trust and confidence among coalition participants have been highlighted throughout the DMT exercises.

DMT technical challenges such as long-haul secure networks, high-fidelity simulation, standard protocols and requisite bandwidth have been overcome with this mature technology and standards have now been clearly established. On-going studies of behaviour indicators for combat crew readiness continue with a structured measure of performance and assessment tools being pursued. In supporting DMT networked technology, the full establishment of an interoperable, user-friendly, briefing/debriefing system with a structured ROE continues to positively evolve.

In association with this DMT technology, the CF must continue to strengthen its *interoperability* with the U.S. armed forces, *training together* and pursuing collaborative ways to

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Training…, 8.

respond to emerging asymmetric threats. The CF must manage its interoperability relationship with the United States and other allies to permit seamless operational integration at short notice.[108]

DMT is relevant to domestic, NORAD operations, and will also allow NATO, and coalition partners to *practice together* in large, complex, Composite Air Operation (COMAO) packages providing participants with focused *feedback* and will help build *confidence and trust* in their coalition partner capabilities. NATO Exercise First Wave, a DMT synthetic exercise planned for September 2004 with Canadian participation, will provide the next step and continued growth in the evolution of DMT with other NATO partners.

As the CF-18 community embarks on its Advanced Distributed Combat Training System (ADCTS) project and DND with the Canadian Advanced Synthetic Environment (CASE) initiative, the CF will keep pace with other coalition countries setting up a DMT network that is interoperable with existing U.S. and U.K. DMT sites. This will be an innovative approach to coalition training, with crews being ready for combat operations when called upon.

In the future, mission rehearsal functionality and deployability will remain key elements in the DMT evolution. With the CF-18's multi-role capability and the potential for long deployments (i.e., Kosovo 1999), skills maintenance and continued crew readiness will remain a vital concern for CF leaders and their war fighters.

A key element of the CF air force transformation, force modernization, and *capability-based planning* process revolves around the growing importance of a joint combat capability and interoperability. As stated by the Canadian Chief of Defence Staff (CDS), *joint and combined thinking in a networked environment* will enable new and stronger war fighting behaviours.[109]

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[108]Department of National Defence, Part II: *Strategy 2020 – Canadian Defence into the 21st Century,* June 1999, 5; available from http://www.forces.gc.ca/pubs/anrpt2003/capabilities_e.asp; Internet; accessed 08 January 2004.
[109]Department of National Defence, *Chief of the Defence Staff Annual Report 2002-2003;* available from http://www.cds.forces.gc.ca/pubs/anrpt2003/capabilities_e.asp; Internet; accessed 08 January 2004.

As the USAF and other coalition partners transition to DMO operations, DMT will form a critical part of this larger umbrella. The way ahead for Canada with networked technology and future coalition operations involves combat crews and command and control units working together at the joint force level.

To reiterate, *interoperability* is the key and does not just apply to platforms, but to roles and personnel, policy, procedures and doctrine. Interoperability requires understanding, co-operation, communication and primarily *trust*.[110] DMT will provide this mechanism to establish the training necessary and the trust and confidence amongst the coalition partners and their combat ready crews. DMT will help prepare our fighter force for future NATO and coalition type missions and fill that void that currently exits.

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[110]McIntyre, Smith, and Bennett, *Exploiting High Fidelity Simulation for Aircrew Coalition Mission Training…,* 10.

The key points to remember: Interoperability and Trust in a coalition environment are vital. With DMT and its enhanced combat readiness capability, you can now “Train the way you fight!”

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ANNEX B

ACRONYM LIST

AAA	Anti-Aircraft Artillery
AAR	Air-to-Air Refueling
ACE	Air Combat Emulator
ACMI	Air Combat and Maneuvering Instrumentation
ADCTS	Advanced Distributed Combat Training System (CF-18 Project)
ADDNS	Advanced Deployable Day/Night Simulation (DRDC project)
ADMS	Advanced Distributed Mission Simulation
AFA	Air Force Association
AFRL	Air Force Research Laboratory (Mesa, Arizona)
ALSP	Aggregate Level Simulation Protocol
ATC	Air Traffic Control
ATO	Air Tasking Order
AWACS	Airborne Warning and Control System
BAI	Battlefield Air Interdiction
BARS	Behaviourally Anchored Rating Scales
BFM	Basic Fighter Maneuver
BVR	Beyond Visual Range
C2	Command and Control
C2ISR	Command, Control, Intelligence, Surveillance and Reconnaissance
C4I	Command, Control, Communications, Computer and Intelligence
CAOC	Combined Air Operations Center
CAP	Combat Air Patrol
CAS	Close Air Support
CASE	Canadian Advanced Synthetic Environment
CDS	Chief of the Defence Staff
CF	Canadian Forces
CGF	Computer Generated Forces
CMTR	Coalition Mission Training Research
COMAO	Composite Air Operations
COTS	Commercial Off-the-Shelf
CTO	Collective Training Objectives
CQWI	Combined Qualified Weapons Instructor (UK)
DACT	Dissimilar Air Combat Training
DAR	Directorate of Aerospace Requirements
DCA	Defensive Counter Air
DIS	Distributed Interactive Simulation
DMO	Distributed Mission Operations
DMOC	Distributed Mission Operations Center
DMSO	Defense, Modeling and Simulation Office
DMT	Distributed Mission Training
DPG	Defence Planning Guidance
DRDC	Defence Research and Development Canada
ECCM	Electronic Counter-Counter Measures
ECP	Engineering Change Proposal

EM	Electromagnetic
EW	Electronic Warfare
FLIR	Forward Looking Infrared
FOM	Federation Object Model
FWIC	Fighter Weapons Instructor Course (CF)
G	Gravity
GBAD	Ground Based Air Defence
GCI	Ground Control Intercept
GPS	Global Positioning System
HLA	High Level Architecture
HOTAS	Hands-On Throttle and Stick
HUD	Heads-Up Display
IEEE	Institute of Electrical and Electronics Engineers
IFF	Identification Friend or Foe
I/ITSEC	Interservice/Industry Training, Simulation, and Education Conference
IM	Information Management
IMP	CF-18 Incremental Modernization Project
IOS	Instructor Operator Station
IPUG	Instructor Pilot Upgrade Training
ISDN	Integrated Services Digital Network
ISR	Intelligence, Surveillance and Reconnaissance
JFACC	Joint Force Air Component Commander
JNTC	Joint National Training Facility
JSTARS	Joint Surveillance Target Attack Radar System
LGB	Laser Guided Bomb
MCE	Mapping and Charting Establishment (DND)
MEC	Mission Essential Competencies
MOP	Measurement of Performance
MSG	Modeling and Simulation Group (NATO)
MTC	Mission Training Center
MTDS	Mission Training via Distributed Simulation (NATO term)
MTT	Multi-Task Trainer
MWC	Maritime Warfare Center
NAM	NATO Air Meet
NATO	North Atlantic Treaty Organization
NEO	Non-Combatant Evacuation Operation
NGTS	Next Generation Threat System
NORAD	North American Aerospace Defence
NTS	Networked Tactical Simulator (CASE project)
NVG	Night Vision Goggle
OCA	Offensive Counter Air
OFP	Operational Flight Program
OFTT	Operational Flight Tactics Trainer (older CF-18 simulator)
OOTW	Operations Other Than War
OTU	Operational Training Unit
PDU	Protocol Data Units
PETS	Performance Effectiveness and Evaluation Tracking System
PFPS	Portable Flight Planning System

PGM	Precision Guided Munitions
PTT	Part-Task Trainer
RMA	Revolution in Military Affairs
ROE	Rules of Engagement
RTI	Run Time Infrastructure
RTO	Research and Technology Organization (NATO)
RWR	Radar Warning Receiver
SAS	Studies, Analysis and Simulation Panel (NATO)
SCP	Strategic Capability Planning
SEAD	Suppression of Enemy Air Defence
SIMNET	Simulator Network
SISO	Simulation Interoperability Standards Organization
SMART	Simulation, Modeling, Acquisition, Rehearsal and Training
SME	Subject Matter Expert
SNE	Synthetic Natural Environment
SOM	Simulation Object Model
SOR	Statement of Operational Requirement
TACCSF	Theatre Aerospace Command, Control Simulation Facility (Kirtland AFB)
TAMMS	Tactical Aviation Mission System Simulator (CH-146 Simulator)
TD IPT	Training Development Integrated Product Team
TDP	Technology Demonstration Project (DRDC)
TIALD	Thermal Imaging Airborne Laser Designator
TLP	Tactical Leadership Program (NATO)
TNA	Training Needs Analysis
TRDP PA	Technology Research and Development Program – Project Arrangement
TSOR	Technical Statement of Operational Requirement
TTCP	Technical Training Cooperation Program
UAV	Unmanned Aerial Vehicle
WAN	Wide Area Network
WAVE	War Fighter Alliance in a Virtual Environment (Exercise First Wave)
WST	Weapon System Trainer
YFR	Yearly Flying Rate

DISTRIBUTED INTERACTIVE SIMULATION (DIS) VERSUS HIGH LEVEL ARCHITECTURE (HLA)

DMT can use a standard *architecture,* which will allow reuse and interoperability of a wide range of virtual and live systems. The architectures for networked simulations have evolved over time. The Simulator Networking (SIMNET) project in the late 1980's demonstrated both a novel technology and an alternative approach to simulator training based on multiple players gaining experience in unstructured, real-time combat scenarios.[111] Since SIMNET, DMT and related systems now provide scenario-based, team training using interacting, real-time, virtual and constructive simulators. The improved DMT capability has been largely due to the architecture of *Distributed Interactive Simulation (DIS).* DIS was developed from the U.S. Army's SIMNET program, was under development for approximately 10 years, and is now considered a fully mature simulation networking technology. DIS is a networking protocol standard that provides a method of communicating an entity[112] state and other information through Protocol Data Units (PDUs). These PDUs are data packets that are sent out at regular intervals or whenever significant interactive events happen within a simulation. In the DIS protocol, every simulator in a participating group has access to all PDUs that are issued by every other simulator, which causes a bandwidth problem when networks become too large. PDUs can be defined as a "structured message, which transfers essential data of a specific type from one DIS entity to all others and allows them to participate in a common exercise."[113]

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[111] Peter Crane and Herbert Bell, *Similarities and Differences in the Implementation of Distributed Mission Training*, 1. Proceedings of the Interservice/Industry Training, Simulation, and Education Conference (I/ITSEC) 2002 Conference.

[112] Peter Clark, Peter Ryan and Lucien Zalcman, *Advanced Distributed Simulation for the Australian Defence Force* (Adelaide: Defence Science and Technology Organization, October 2000), 68.
Definition -*Entity* – An identifiable individual component within a simulation. An entity might be a platform (aircraft), a munition (missile), a human being or any other component that interacts with the simulation.

[113] *Ibid*, 72.

Since DIS is an Institute of Electrical and Electronics Engineers (IEEE) standard, any simulator connected to the network and implementing the same version of the DIS protocols can participate in a DIS exercise. The basic concepts of DIS and potential advantages include the following:

a. no central computer controls the entire simulation exercise;

b. simulation applications are autonomous and are responsible for maintaining the state of one or more simulation entities or components;

c. standard protocol is used for communicating the absolute truth about the state of the entity it controls to other simulations on the network; and

d. dead reckoning algorithms are used to reduce the communications processing.[114]

DIS provides a standard means for interconnecting simulators with a significant development of commercial off-the-shelf (COTS) applications such as scenario generators, viewers, data loggers and analysis toolkits. In addition, through the Simulation Interoperability Standards Organization (SISO), DIS provides a highly comprehensive set of weapons and sensor components (i.e., entities) that include the majority of U.S., Russian, U.K., French and German inventory. Network packet formats are fully defined, allowing compatible simulators or simulations to interoperate in a plug and play fashion. In addition, a DIS test suite has been developed that can test DIS compliance of simulators before participation in DIS exercises, in an accredited automated environment.

DIS does however have some limitations in its application. Although DIS is a standard protocol, it is sometimes viewed as rigid and inflexible, requiring high computational requirements and network bandwidth for very large-scale networked systems. DIS code is not portable when using a different DIS toolkit from a different toolkit supplier. DIS also has potential insecurity because PDUs are a

[114] *Ibid*, 2-3.

published standard, which would allow eavesdropping of exercises. The fidelity of the models may differ significantly between participating simulators, resulting, potentially in unfair fights.[115] DIS has limited support for entity collection and is designed specifically for real time platforms such as manned flight simulators. DIS is unsuitable for the networking of faster than real time (repeatable), constructive simulations, and, so, a separate and incompatible protocol, the Aggregate Level Simulation Protocol (ALSP) was independently developed. However, virtual and constructive simulations were not interoperable with these implementations, and many legacy models complied with neither standard. This led to the development of the High Level Architecture (HLA).

Now the US DOD agency, Defense Modeling and Simulation Office (DMSO), which is responsible for outlining policy and strategic direction for modeling and simulation with the U.S. military, has mandated the *High Level Architecture (HLA)* as the future replacement for DIS. HLA is an object-oriented approach towards simulator and simulation interoperability. HLA uses the concept of a federation, which is a collection of individual simulations (i.e., federates) linked together and distributed across large geographical distances. HLA is defined by the rules that specify how simulations interact and the Run Time Infrastructure (RTI) software that provides the means and management to exchange data during execution.[116]

Simulations within the HLA architecture are called federates and a set of participating federates is known as a federation. Each federate must have an associated Simulation Object Model (SOM), which describes its data requirements for modeling entities. To form a group of participating federates known as a federation, a Federation Object Model (FOM) must be developed. This FOM has the same structure as the SOM's and identifies the attributes and interactions supported by the federation. Where DIS specifies fixed formatted PDUs, HLA will

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[115] *Ibid*, 6.

let the user define what data, in what format, are required to be interchanged among federation members. Therefore, HLA has the potential to be considerably more efficient than DIS. Only the data required to support a federation need be sent over the network rather than the redundant data sent in the DIS PDUs. In addition, HLA should only send data that has changed. Therefore, the main advantage of HLA is that it will reduce the required bandwidth. HLA will support both real time and enable interaction between both virtual and constructive simulations that may use non-real time. A further advantage of HLA is that since data broadcast is FOM specific, it will have an *automatic level of security* as they will need to have knowledge of the specific FOM data content and formats.

With respect to disadvantages of HLA, unless all federates agree on an FOM, they will not be able to interoperate even though they are HLA compliant. Each FOM will need its own listing of weapons and sensors, development of dead-reckoning algorithms, viewers, loggers and analysis toolkits.

HLA is a new and exciting technology that will ultimately offer many advantages over DIS. It may however be premature to mandate its use because it may compromise interoperability with U.S. and other allies. As a result of the U.S. DoD's mandating of HLA, considerable effort has been applied to provide a means of enabling DIS-compliant systems to upgrade to HLA. In the interim, migration of DIS to HLA is available via a gateway, which translates DIS PDUs and HLA services in both directions in real time while the simulation exercise is in progress. This may result in additional latency. Where the benefits of HLA (i.e., interaction with constructive simulators, reduced broadcasting of data) are not required, the gateway will be the most effective way to retain the benefits of interoperability by DIS while still having the ability to connect via HLA.

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[116] *Ibid*, 7.

ANNEX D

PERFORMANCE MEASUREMENT

A primary purpose of performance measurement is to identify strengths and weaknesses in the knowledge and skills necessary for successful air combat so that training can be focused on addressing identified MEC deficiencies. By defining Measures of Performance (MOP) in terms of the knowledge and skill elements that contribute to task performance, MOPs can serve as a link between training, essential knowledge and skills and performance outcomes.

Assessment of trainee performance has been problematic in the past for many reasons, which include for example, the scenarios, which contain many different elements and encompass a wide variety of complexities. Variables used in creating scenarios include mission type (i.e., OCA, DCA), number of enemy aircraft, types of aircraft and ordnance, number of groups, group formations and maneuvers, and the level of enemy aggressiveness and reactivity.[117]

One problem has been in quantitatively assessing changes in team performance over several days of training. One potential solution has been to develop a set of benchmark missions that have been judged by Subject Matter Experts (SMEs) as similar in overall complexity. In previous research exercises, teams fly one benchmark mission early in the week and performance is compared to a different benchmark flown later in the week. Performance changes on these two missions allow comparisons from the beginning of training to the end for each of the rated skills and competencies. With scores on benchmark as a starting point, a next and critical step is the establishment of some process whereby the complexity of each scenario can be accounted for in assessment of performance. What is needed is some type of overall degree of complexity scale that could be applied within and across all scenarios in a syllabus. This is difficult because an empirically based scale value only indicates rank order of complexity rather than the degree of complexity. Modifications to scenarios may change the tactical situation but not necessarily changing the overall complexity of the mission. On the other hand, changing enemy aircraft armament from shorter-range radar missiles to longer-range missiles greatly increases the complexity without increasing the number of enemy aircraft.[118]

An alternative approach to constructing a complexity scale for scenarios is to ask SMEs to make direct judgments of complexity, or compare scenarios and use mathematical procedures to extract a scenario degree-of-complexity scale from these judgments. This research was validated from June to July 2001 at Mesa Arizona with 31 F-16 pilots participating in a DMT effectiveness research exercise. With a range of inexperienced and experienced F-16 pilots and AWACS controllers, flying DMT sessions for a one week period, they were asked afterwards to rate 30 scenarios in rank order from the easiest to the most complex. A scenario was determined simple if pilots had a high probability of completing their mission objectives using a few basic tactics; a complex mission would require employment of multiple, advanced tactics to complete the mission. The analysis demonstrated a high level of agreement among raters (pilots) with respect to relative complexity of DMT scenarios.[119] The easiest scenarios were characterized by a single wave of aircraft in one or two groups with limited maneuvers. The moderately complex scenarios were characterized by a single wave of four to six aircraft in multiple, maneuvering groups. Moderately complex scenarios included fighters, armed with longer-range missiles and mixed rules of engagement (ROE) including some aircraft that could be identified as hostile beyond visual range (BVR) and others that may be visually identified. The most complex missions were characterized by multiple waves of maneuvering and reactive enemy aircraft with

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[117]Herbert Bell, Peter Crane and Robert Robbins, *Mission Complexity Scoring for Distributed Mission Training*, 4. Proceedings of the Interservice/Industry Training, Simulation, and Education Conference (I/ITSEC) 2001 Conference.
[118]*Ibid*, 4.

mixed rules of engagement. It was determined that complexity scales based on this psychological type scaling process provides an effective method of quantifying trainee progress in a building block program and helps instructors build scenarios to meet specific training objectives.[120]

Now, taking the first step towards achieving a standardized human performance assessment ability for DMT, AFRL in Mesa, Arizona has developed a proof of concept automated distributed Performance Effectiveness and Evaluation Tracking System (PETS) which, overall, collects data from the network and uses it as inputs to different algorithms needed to generate the quantitative measurements for analysis.[121] PETS reside on the network listening to all the data passed through the interface units. From January 2002 to June 2003, PETS has been used to collect, in real-time, data on over 190 F-16 pilots and over 1,300 scenarios. PETS captures over 1,000 variables at 20 hertz, or over one million data points per minute. Most of these data points are related to entity type of positional information but numerous metrics are also used in assessing specific MECs.[122] Performance assessments that are the best candidates for automation, involve skills that have well-defined performance standards or known optimums. Performance standard examples could include CAP roles and formation standards that specify acceptable distance, speed and position parameters. Optimum performance ratings could include the "notch," a defensive skill used by the pilots against adversary radars. Predominantly though, cognitive skills such as assessing a tactical situation present a challenge for automated evaluation techniques.

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[119]*Ibid*, 4.
[120]*Ibid*, 4.
[121]Thomas Carolan, Brian Schreiber, and Winston Bennett, *Integrated Performance Measurement and Assessment in Distributed Mission Operations Environments: Relating Measures to Competencies*, 9. Proceedings of the I/ITSEC 2003 Conference.
[122]Brian Schreiber and Winston Bennett, *Objective Human Performance Measurement in a Distributed Environment: Tomorrow's Needs*, 7. Proceedings of the I/ITSEC 2003 Conference.

Observed performance in any given situation may rely on a number of different skill and knowledge elements. A major challenge for developing observation based performance ratings is deciding where to focus the observers attention for measurement. The SPOTLITE method developed in the United States under the sponsorship of AFRL, addresses the difficult problem of focusing performance measurement in a complex multi-person simulation based training environment. In SPOTLITE with respect to F-16 pilots, given a list of skills and knowledge (based on MECs), SMEs identified a series of relevant and key performance indicators (specific behaviours indicating readiness). This approach allowed training analysts to identify those behaviours and points in the scenario where measurement will yield the most valuable diagnostic results. SPOTLITE provides a method of understanding what should be measured for air combat missions for that specific platform. It is realized that not all behaviours can be seen in a simulation based training environment (i.e., effects of g on the pilot), but the combination of *what should* be measured based on the desired competencies and *what could* be measured in the training environment, gives us the basis for generating an initial set of performance measures. With SPOTLITE, the MEC structure does provide a basis for structuring scenarios so that observation based measurement can be focused on specific, observable behaviors that are linked to specific events and competencies. The goal is to obtain data directly from the simulation wherever possible, reserving the expert judgment and necessarily limited attention of observers for assessing those behaviours that are not easily assessed through automated means.[123]

To note, DRDC Toronto has also done some research on the development of generic aircrew measures of performance for distributed mission training. The DRDC report reiterated a set of five behavioural processes that could be measured:

a. functional allocation/crew resource management;

[123]Carolan, Schreiber and Bennett, *Integrated Performance Measurement and Assessment in Distributed Mission*

b. tactics employment;

c. situational awareness;

d. command and control communications; and

e. time management.[124]

The DRDC/contractor report identified strategies for measuring performance which include: *objective performance data, Behaviourally Anchored Rating Scales* (BARS) scored by SME, and the Pathfinder Approach. Note, the Pathfinder approach, which deals with assessment of crew knowledge structures is beyond the scope of this paper and will not be discussed.

Similar to the PETS concept described above, *objective performance* represented four measures that include: response time, duration, accuracy (error), and frequency. It was highlighted though that this measurement is not immune to challenges of validity and reliability. In concert with the SPOTLITE mentioned previously, *BARS* and its rating scales is one of the methods of choice for AFRL in Mesa. A number of common errors that should be highlighted with the use of the BARS rating scale include the following:

a. errors of leniency;

b. sequential errors when later ratings are affected by earlier ones;

c. distribution errors where ratings tend to congregate around middle values and result in a lack of discrimination; and

d. halo-effect where a crew that is highly effective at the beginning of a mission, may tend to be rated higher in subsequent engagements even when the performance does not warrant it.[125]

Operations Environments: Relating Measures to Competencies…, 6.

[124]Michael Matthews and Tabbeus Lamoureux, *Development of Generic Aircrew Measures of Performance for Distributed Mission Training*, Report prepared for Defence Research and Development Canada (DRDC), DRDC document no. CR-2003-060, (Toronto: 31 March 2003), 17.

[125]*Ibid*, 31.

AFRL studies have refined the BARS process and clearly demonstrated the reliability, validity and sensitivity of this process and that it is an effective tool to assess and measure the relationship between mission planning and mission performance.[126]

By assessing performance process in addition to performance outcomes, training interventions, such as post-exercise debrief and the design of *training events, can be focused on identified process weaknesses.* Objective simulation-based measures and observation-based measures *together* provide a rich basis for assessment of the knowledge and skills that support each MEC. By using a common measurement framework, observation and simulation based data can be integrated to provide assessments at the knowledge, skill and MEC level.[127]

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[126]*Ibid*, 31.
[127]Carolan, Schreiber and Bennett, *Integrated Performance Measurement and Assessment in Distributed Mission Operations Environments: Relating Measures to Competencies*…, 9.