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JSMARTS Initiative:

*Advanced Distributed Simulation across the Government
of Canada, Academia and Industry – Technical Description*

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M. Gamble, R. Lavoie, D. Kurts and K. Gladstone

Defence R&D Canada – Ottawa

TECHNICAL MEMORANDUM

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Abstract

JSMARTS (Joint Simulation, Modeling for Material Acquisition, Requirements, Training and Support), or Joint SMARRT (Simulation and Modeling for Acquisition, Requirements, Rehearsal and Training) represents a new concept for DND (Department of National Defence), it is conceptualized as a vision of M&S (Modeling & Simulation) at the Enterprise level, led by ADM(Mat). In an effort to reduce the technical risk associated with networking simulation stakeholders at various levels of the DND Enterprise, a WAN (Wide Area Network) distributed simulation was executed, regrouping in the same virtual environment (Synthetic Environment) the Government of Canada, Industry and Academia. In this HLA (High Level Architecture) Federation, the national Canarie Network was selected as the common, non-dedicated, unclassified, VPN-encrypted network procuring connectivity between Federates. While CAE Inc. was providing CGF (Computer Generated Forces), DRDC Ottawa's FFSE Section was providing a UAV (Uninhabited Aerial Vehicle) simulator, a NATO STANAG 4586 compliant Ground Control Station, both supported by the Joint Simulation Network. (JSIMNET: FFSE's persistent simulation capability). Finally, Carleton University provided a NTS (Networked Tactical Simulator) CH 146 Griffon helicopter human-in-the-loop simulator. DAR (Director Aerospace Requirements) graciously provided pilots, whereas the UAV aircrew was provided by CFEC (Canadian Forces Experimentation Centre). To reduce the FEDEP (Federation Development and Execution Process) development time to a bare minimum, different FOMs (Federation Object Models) and different RTIs (Run Time Infrastructures) were used but bridged by a remapping middleware tool. Finally, since a common SE (Synthetic Environment) tool, STRIVE, existed amongst participants, it was used across all organizations, further simplifying development time. CH146 NTS pilots and UAV Aircrew were engaged in 3 separate experimental conditions while human performance measurements were collected. This document provides a technical summary of the technical issues directly related in the successful execution of the present Exercise.

This study has demonstrated a successful case of interoperable HLA-based distributed simulation across Government of Canada, Industry and Academia. Further, this study suggests that harmonization, coherence and alignment with international standards, international protocols as well as common tools ensured quick reusability of existing simulation capabilities in the participating organizations, for maximum interoperability.

Résumé

Le projet JSMARTS (simulation et modélisation conjointes pour l'acquisition du matériel, les besoins, l'entraînement et le soutien), ou SMARRT (simulation et modélisation pour l'acquisition, les besoins, la répétition et l'entraînement) conjoint, représente un nouveau concept pour le MDN (ministère de la Défense nationale), il est conceptualisé sous forme d'une vision de modélisation et de simulation (M et S) au niveau de l'entreprise, menée par SMA(Mat). Dans le but de diminuer le risque technique relié à la simulation de réseautage des parties intéressées à divers niveaux de l'entreprise du MDN, on a effectué une simulation répartie à réseau de zone étendue (WAN) qui regroupait le même environnement virtuel (environnement synthétique) du gouvernement du Canada, de l'industrie et du monde universitaire. Dans cette fédération d'architecture évoluée (HLA), on a retenu le réseau national Canarie comme réseau privé virtuel encodé commun, non spécialisé et non protégé, qui assurait la connectivité entre les organisations fédérées. La firme CAE Inc. a fourni les forces générées par ordinateur (CGF), la section ESFF du RDDC Ottawa a fourni un simulateur d'engin télépiloté et le poste de contrôle au sol connexe conforme à la STANAG 4586 de l'OTAN, les deux soutenus par le réseau de simulation conjoint (JSIMNET : capacité de simulation constante du ESFF). Enfin, l'établissement Carleton University a fourni un simulateur tactique réseauté (NTS) où l'humain fait partie de la boucle pour l'hélicoptère CH 146 Griffon. Le Directeur - Besoins en ressources aérospatiales (DBRA) a obligeamment fourni les pilotes, tandis que l'équipage de conduite de l'engin télépiloté a été fourni par le Centre d'expérimentation des Forces Canadiennes (CEFC). Afin de réduire le plus possible le temps d'élaboration du FEDEP (élaboration de fédération et processus d'exécution), on a utilisé différents modèles objets de fédération (FOM) et différentes infrastructures de temps d'exécution (RTI) que l'on a reliés au moyen d'un intergiciel de remappage. Finalement, puisqu'un outil commun d'environnement synthétique (STRIVE) existait déjà parmi les participants, on a utilisé cet outil pour toutes les organisations, ce qui a simplifié encore plus le temps de développement. Les pilotes du NTS du CH146 et l'équipage de conduite de l'engin télépiloté ont participé à trois expériences distinctes pendant lesquelles on mesurait les performances humaines. Le présent document fournit un résumé technique des questions techniques directement reliées à la réussite du présent exercice.

La présente étude a démontré un cas réussi de simulation répartie à architecture évoluée interopérable entre le gouvernement du Canada, l'industrie et le monde universitaire. De plus, cette étude laisse croire que l'harmonisation, la cohérence et la conformité avec les normes et les protocoles internationaux, de même que l'utilisation d'outils communs sont susceptibles d'assurer une réutilisabilité rapide des capacités de simulation existantes dans les organisations participantes, de manière à assurer une interopérabilité maximale.

Executive summary

While distributed simulations have taken place in Canada since at least the 1990s, using mostly the DIS (Distributed Interactive Simulation) / IEEE 1278 standard or HLA (High Level Architecture) /IEEE 1516, very few have involved the Government of Canada, Academia and Industry in a joint exercise. JSMARTS, or Joint SMARRT represents a new vision for DND, a vision of M&S at the Enterprise level, led by ADM(Mat).

In an effort to reduce the technical risk associated with networking simulation stakeholders at various levels of the DND Enterprise, a WAN (Wide Area Network) distributed simulation was executed, regrouping in the same virtual environment (Synthetic Environment) the Government of Canada, Industry and Academia. In this HLA Federation, the national Canarie Network was selected as the common and preferred non-dedicated, unclassified, VPN-encrypted network procuring connectivity between Federates. The participants are,

- CAE Inc.: provided CGF (Computer Generated Forces)
- FFSE/DRDC Ottawa: provided a UAV Simulator, a NATO STANAG 4586 compliant Ground Control Station, both supported by the Joint Simulation Network (JSIMNET)
- Carleton University: provided an NTS (Networked Tactical Simulator) CH 146 Griffon Helicopter human-in-the-loop simulator
- DAR (Director Aerospace Requirements): provided Ch146 pilots
- CFEC (Canadian Forces Experimentation Centre): provided the UAV aircrew

To reduce the FEDEP (Federation Development and Execution Process) development time to a bare minimum, different FOMs (Federation Object Models) and different RTIs (Run Time Infrastructures) were used but bridged by a remapping middleware tool. Finally, since a common SE (Synthetic Environment) tool, STRIVE, existed amongst participants, it was used across all organizations, further simplifying development time. CH146 NTS pilots and UAV Aircrew were engaged in 3 separate experimental conditions while human performance measurements were collected. The repeated measures experimental schema is described below:

- Scenario 1: A sole CH-146 Griffon Helicopter operating on its own
- Scenario 2: A CH-146 and a UAV operating with a third party comms link.
- Scenario 3: A CH 146 and a UAV with a direct data link in addition to the comms link.

This document provides a summary of the technical issues directly related in the successful execution of the present Exercise. This study has demonstrated a successful case of an interoperable HLA based distributed simulation across GOC, Industry and Academia. Further, this study suggests that harmonization, coherence and alignment with international standards, international protocols as well as common tools ensured quick reusability of existing simulation capabilities in the participating organizations, for maximum interoperability.

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Sommaire

Même si des simulation réparties ont eu lieu au Canada depuis au moins les années 1990, à l'aide principalement de simulations interactives réparties (DIS) de norme IEEE 1278 ou d'architectures évoluées (HLA) de norme IEEE 1516, il y a eu très peu de simulations dans un exercice conjoint entre le gouvernement du Canada, le monde universitaire et l'industrie. Le JSMARTS, ou SMARRT conjoint, représente une nouvelle vision pour le MDN, une vision de M et S au niveau de l'entreprise, menée par SMA(Mat). Dans le but de diminuer le risque technique relié à la simulation de réseautage des parties intéressées à divers niveaux de l'entreprise du MDN, on a effectué une simulation répartie à réseau de zone étendue (WAN) qui regroupait le même environnement virtuel (environnement synthétique) du gouvernement du Canada, de l'industrie et du monde universitaire. Dans cette fédération d'architecture évoluée (HLA), on a retenu le réseau national Canarie comme réseau privé virtuel encodé commun, non spécialisé et non protégé, qui assurait la connectivité entre les organisations fédérées. Les organisations participantes sont :

- la firme CAE Inc. qui a fourni les forces générées par ordinateur (CGF)
- la section ESFF du RDDC Ottawa qui a fourni un simulateur d'engin télépilote et le poste de contrôle au sol connexe conforme à la STANAG 4586 de l'OTAN, les deux soutenus par le réseau de simulation conjoint (JSIMNET)
- l'établissement Carleton University qui a fourni un simulateur tactique réseauté (NTS) où l'humain fait partie de la boucle pour l'hélicoptère CH 146 Griffon.
- le Directeur - Besoins en ressources aérospatiales (DBRA) qui a obligeamment fourni les pilotes
- le Centre d'expérimentation des Forces Canadiennes (CEFC) qui a fourni l'équipage de conduite de l'engin télépilote.

Afin de réduire le plus possible le temps d'élaboration du FEDEP (élaboration de fédération et processus d'exécution) on a utilisé différents modèles objets de fédération (FOM) et différentes infrastructures de temps d'exécution (RTI) que l'on a reliés au moyen d'un intergiciel de remappage. Finalement, puisqu'un outil commun d'environnement synthétique (STRIVE) existait déjà parmi les participants, on a utilisé cet outil pour toutes les organisations, ce qui a simplifié encore plus le temps de développement. Les pilotes du NTS du CH146 et l'équipage de conduite de l'engin télépilote ont participé à trois expériences distinctes pendant lesquelles on mesurait les performances humaines. Le cadre expérimental de mesures répétées est décrit ci-après:

- Scénario 1 : Un seul hélicoptère CH-146 Griffon utilisé isolément.
- Scénario 2 : Un CH-146 et un engin télépilote utilisés avec une liaison commune avec une tierce partie.
- Scénario 3 : Un CH 146 et un engin télépilote utilisés avec une liaison de données directe en plus de la liaison commune.

Le présent document fournit un sommaire des questions techniques directement reliées à la réussite du présent exercice. Cette étude a démontré un cas réussi de simulation répartie à architecture évoluée interopérable entre le gouvernement du Canada, l'industrie et le monde universitaire. De plus, cette étude laisse croire que l'harmonisation, la cohérence et la conformité avec les normes et les protocoles internationaux, de même que l'utilisation d'outils communs sont susceptibles d'assurer une réutilisabilité rapide des capacités de simulation existantes dans les organisations participantes, de manière à assurer une interopérabilité maximale.

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1. Overview

In June 2004 the Canadian DND Assistant Deputy Minister (Materiel) proposed an overarching “Joint SMARTS” (JSMARTS) vision whereby the development and use of M&S knowledge, international M&S standards and M&S interoperability would exist not only in DND but across GOC, Academia, and Industry. In accordance with this vision, DRDC Ottawa, Carleton University and CAE Inc. conducted a JSMARTS interoperability experiment whereby the Uninhabited Air Vehicle Research Test Bed (UAV RTB) at DRDC Ottawa was linked with a CH146 Griffon Networked Tactical Simulator (NTS) at Carleton University. CAE Inc. provided constructive assets to facilitate interoperability between the two sites and to advance the architecture and core capabilities of the NTS system at Carleton University. This JSMARTS initiative has been termed the **“UAV-NTS SE Experiment”** (attached CD contains DND-approved short video clips in both languages).

This initiative was put in place to investigate use of M&S within the JSMARTS context, or M&S at the Enterprise level. It was also designed to explore several concepts such as:

1. The concept of Rapid implementation of Distributed Simulation: is it possible to develop and execute an HLA federation within a few weeks, or does it always take months or more?
2. Is it possible to use such an initiative as an opportunity to engage other participants in DND, OGDs (including Public Security/Safety communities), Industry, Academia on discussions related to increasing the “critical mass of simulationists” in Canada through presentation of effort and results, i.e.: can we augment the number of interoperable M&S capabilities of Government, Academia and Industry?
3. Is it conceivable to create a persistent ability to easily employ M&S in Government, Academia and Industry to jointly explore/analyze new Capabilities?

2. Objective

The JSMARTS initiative was not about simply connecting simulators together once and dismantling them immediately after the occasion. It was assembled to accomplish sets of three specific objectives: interoperability objectives, technical objectives, and human performance objectives. In terms of overall M&S interoperability, the objective was to execute a distributed HLA simulation with GOC, Academia, and Industry partners in a few weeks at little or no cost. The technical objectives were

obviously dependent on the interoperability objective: all technical objectives were aimed at reducing SE development time to a minimum while executing the Federation using the international HLA Standard protocol. Finally, there was human performance objective as CH146 pilots and UAV aircrew involved in the experiment were tested and measured against a set of criteria in each phase of the experimental design focused on Network-Centric Warfare.

3. Technical Issues related to Connecting Simulation Capabilities for Distributed Mission Ops

3.1 Simulation Capabilities

Two distinct simulation capabilities formed the main HLA-based federates taking part in the distributed exercise, namely the UAV Research Test Bed (UAV RTB) housed at FFSE's facility at DRDC-Ottawa and the Griffon Helicopter simulator housed at Carleton University's ACE lab. Figure 1 gives an overview of the set-up of this distributed federation. Within the UAV RTB at DRDC-Ottawa, a number of other CGF federates were generated and maintained by the STRIVE application.

Technically, there are many ways to ensure connectivity across any federates in a distributed federation; the communities can use:

1. A proprietary or self-owned telecommunication line;
2. A leased dedicated telecommunication Line;
3. A leased (non-dedicated) line;
4. Leased bandwidth on a (non-dedicated) line;
5. A free national infrastructure line;
6. Wireless telecommunication.

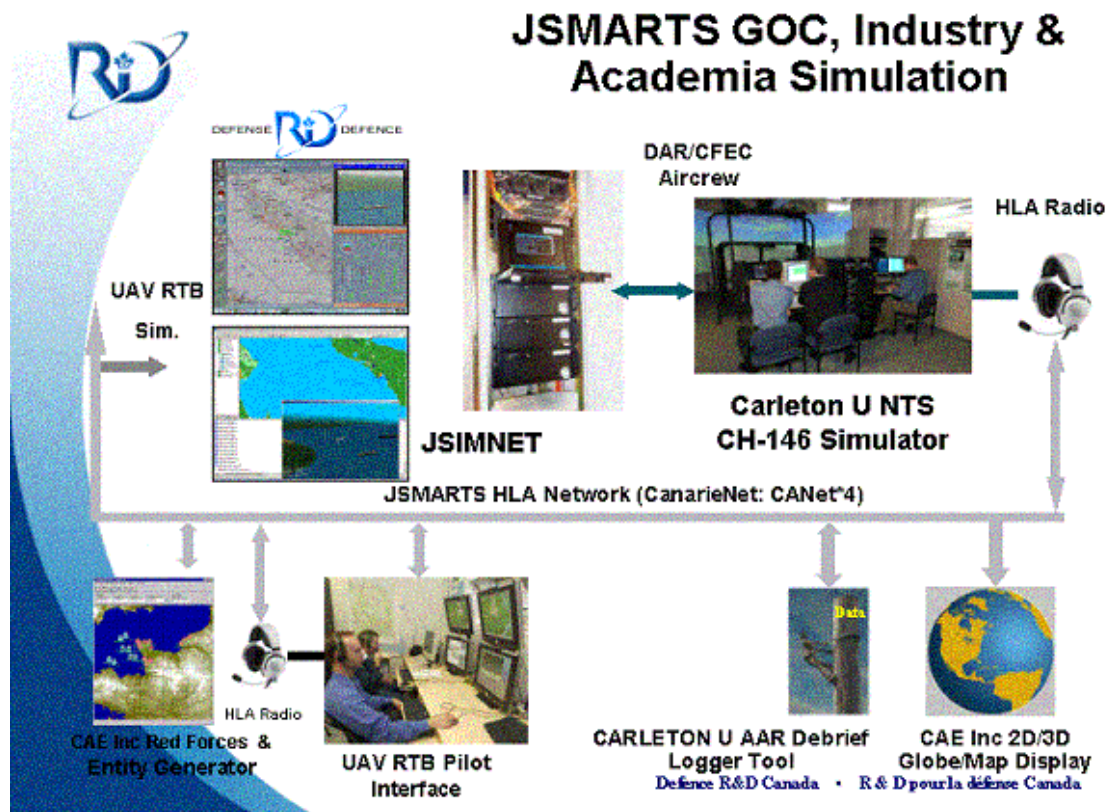


Figure 1: Graphical representation of JSMArts Distributed Simulation layout across three participants: DRDC Ottawa, CAE Inc. and Carleton University

3.2 Distributed Simulation Network

Using a telecommunication line from a free national infrastructure asset appealed to all participants as the fastest technique toward establishing connectivity quickly, with no procurement or contracting involved, though it did not appear to have been fully documented in a Canadian M&S context. Procuring a line or bandwidth meant time and costs and commitment to that schedule, which is an activity that would have pushed the team beyond its 4 week objective.

3.3 Common SE TOOL

A search for a common SE tool was performed as a technique to simplify development and data correlation time. Though other tools could have been used by one or two of the present participants, only one such tool appeared common to all, as it had been regularly used by the participants and all had experience on it; STRIVE

was selected as the common SE tool and agreed upon as a means to smartly manage this particular initiative.

3.4 FEDEP Process, FOM and RTI

In early stage, it was discovered that each proposed JSMARTS federate was mapped to different FOMs. While it had been agreed to tentatively “show leadership” in the community by remapping federates to the latest standard “Military” FOM, the forthcoming SISO Standard “Real Time Platform Reference- Federation Object Model 2.0” (RPR-FOM 2.0; www.sisostds.org), this activity also required time and human resources involvement: i.e.: development time. The situation was further complicated by the discovery that different Run Time Infrastructure (RTI) were presently associated with the respective federates. The UAV RTB employed the STRIVE FOM along with the CAE RTI, while the Griffon simulator used the RPR-FOM 1.0 along with the “DMSO RTI” (now referred to as the HLA 1.3 NG v.6; www.dmsomil). Clearly, this situation appeared to be requiring more time and greater costs involved than anticipated. Clearly one of the objectives, to be able to execute in 4 weeks, was in line with being unrealizable.

3.5 Technical solutions

The Defence community is accustomed to purchasing or leasing its own telecommunications network for a particular Experiment or SE trial. However, there are other networks, such as national infrastructure assets that are presently available to the community, like the national CANARIE Network. The CANARIE Network was created to facilitate the development of Canada’s communications infrastructure and to stimulate next generation products, applications, and services. As a national optical Internet research and education network, it represents the Canadian equivalent to Internet 2, coast-to-coast.

The CANARIE Network interconnects provincial research networks, Universities, Research centres, Government Research laboratories, schools, and other sites, both with each other and with international peer networks, through a series of point-to-point optical wavelengths, most of which are provisioned at OC-192 (10 Gbps) speeds. The CANARIE Network is also the back up network to the Internet for the DRENET, the ADM(S&T) accredited experimental unclassified network connecting all the DRDC Labs across the Nation. By altering the configurations of our PIX Firewalls, we were able to end up with the following network configuration: a non-dedicated , unclassified, VPN-encrypted (as Virtual Private network capability is built –in the Pix Firewall) network. Using VPNs was important and convenient. It enabled the other sites to behave like “enclaves” or extensions to our simulation capability, the JSIMNET (this is entirely analogous to using VPN to remotely tunnel in to work email and work shared drives, with encryption). Since that network is a robust and fast

network, tests were performed to confirm the short enough latency times between sites, prior to any trials. Latencies were on average below 144 milliseconds, well below the threshold where SMEs (Subject Matter Experts) of virtual simulations indicate that human-in-the-loop simulations could start to be affected by a poor latency between action and reaction (about 350 ms; Gamble-Vallerand, March 2004 personal communication). Further, this approach to connectivity is fully consistent with the “Security procedures, rules and regulations stated in “JSIMNET Security guidelines for NON-DRENET Connections” (Skinner & Vallerand, 2005).

The concept of performing distributed simulation with different FOMs was rejected. We had already been in a position to collect data in such a situation and error messages continuously stated that object attributes could not be found, due to errors in mapping. Though it had not been tested and reported in the Canadian literature, colleagues at Carleton University had been experimenting with a FOM Gateway known as “Genesa or STRIVE-RTI connect” a COTS tool from CAE Inc. Running such a tool was designed to provide the linkage/re-mapping of these specific attributes within the FOMs during the exercises. Further, this tool was also designed to accommodate different RTIs. This experiment was therefore an excellent opportunity to determine whether distributed simulation can take place with different FOMs and different RTIs. CAE’s STRIVE-RTI connect is a next generation network interconnection system that provides multi-protocol network simulation data routing between simulation systems.

Genesa/STRIVE-RTI connect is designed to

1. Provide FOM adaptability and FOM filtering, granting data exchange between simulation hosts using different FOMs;
2. Provide existing systems with new network capabilities, thus increasing the number of cooperative heterogeneous systems;
3. Act as a multi-protocol-based network node, natively providing interface to standard protocols such as DIS, HLA-1.3 and IEEE-1516.

It also appears as though creating an interface to any other protocol using the API that is provided with the tool can easily extend connectivity features of STRIVE-RTI connect. A description of the system architecture is shown below in Fig 2.

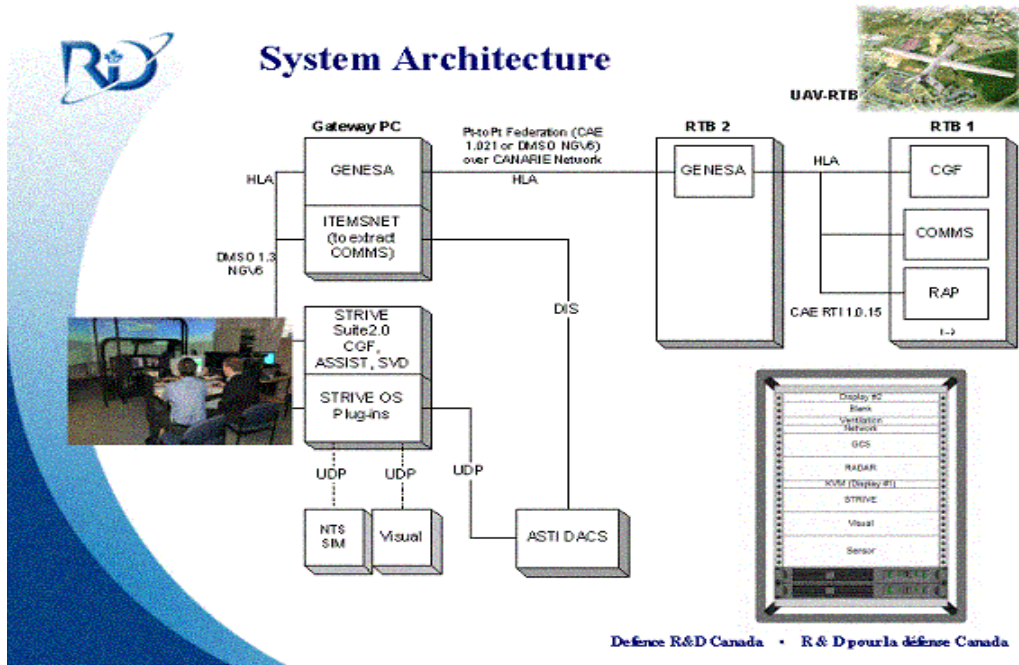


Figure 2: System Architecture.

JSimNet - Carleton ACE Labs Simulation Network Architecture

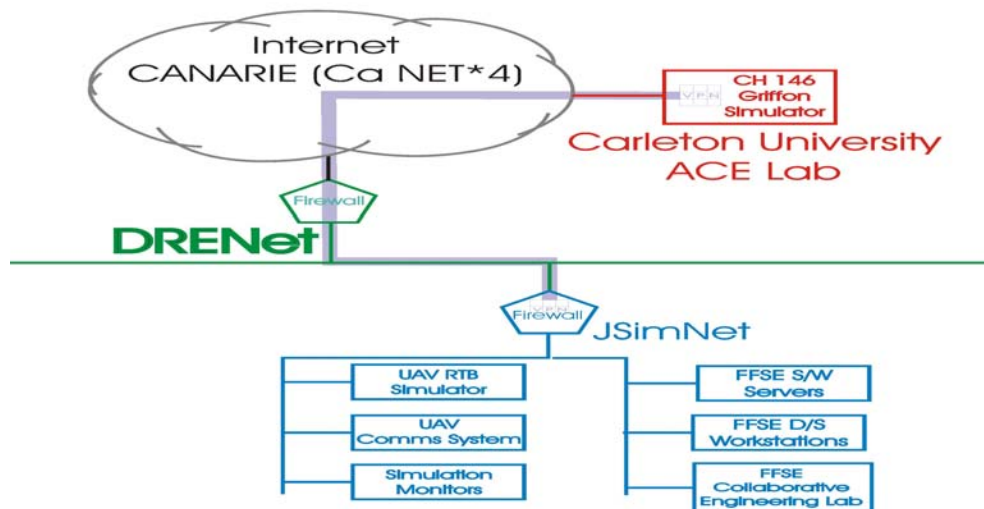


Figure 3: Network Architecture of the JSIMARTS Distributed Simulation layout across GOC, Industry and Academia.

4. FFSE's Persistent Simulation Network and Computer Infrastructure

Using FFSE's persistent simulation capability, the JSIMNET, as a starting point, the JSMARTS synthetic environment work was initiated by networking a certain number of computers together, into dedicated functions. Most of these computers were employed during simulation execution on any particular mission. Of these, approximately twelve computers were used to take part in the HLA federation, and the others were used for distributing data streams to the observation labs (i.e.: Multi-Media Lab used for Live Demonstrations). Figure 4 shows the various PCs involved in the synthetic environment for JSMARTS. Figure 5 also shows the internal components to the RTB (Research Test Bed).

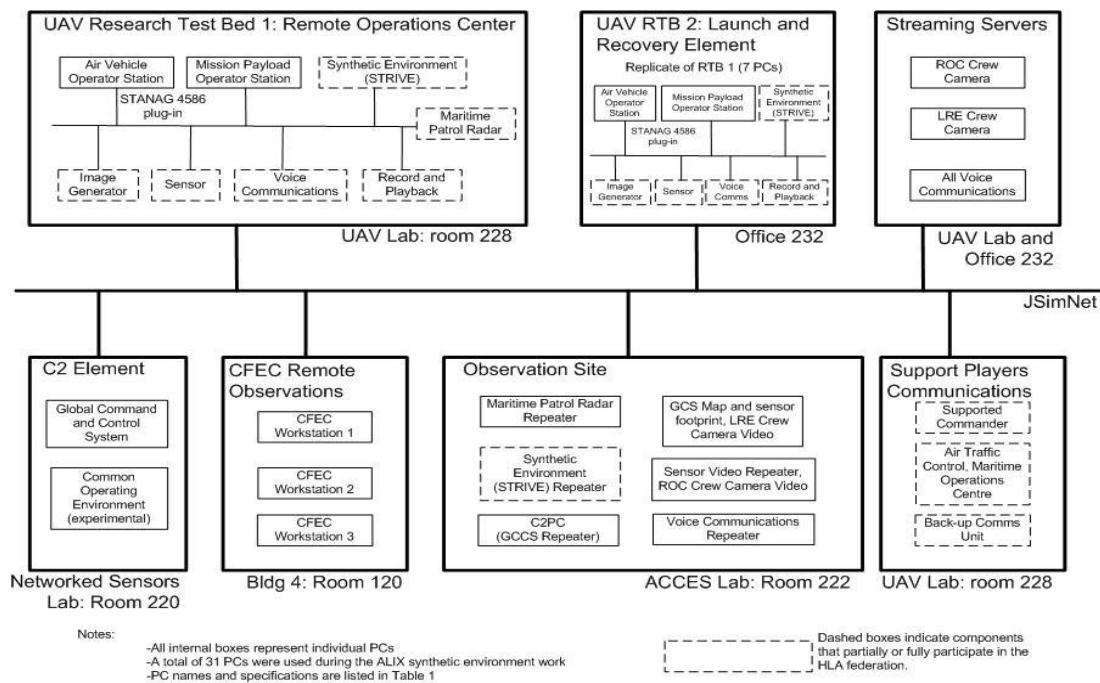


Figure 4: Detailed Network Diagram for JSMARTS SE at FFSE, showing the UAV Research Test Bed 1 (ROC), UAV RTB 2 (LARE), Streaming servers, C2 element, CFEC remote Ops, Observation site, Support Player comms.

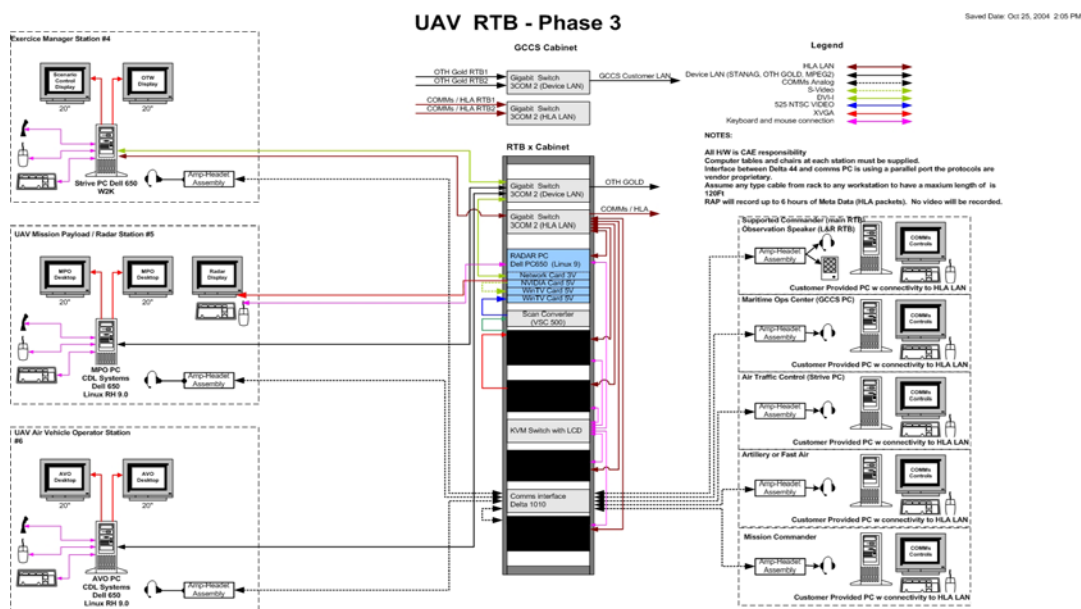


Figure 5: Internal Components of RTB-1

The table below shows the roles and names of the PCs that were used in the JSMARTS SE work. All were “off-the-shelf” personal computers: either desktops or rack-mounted except for one laptop running the command and control personal computer system (explained below). All machines used similar computing power, i.e. known as Pentium Zeon 1.7 GHz with 1GB RAM up to a Pentium Zeon 2.4GHz with 2 GB RAM.

PC Name	Role	Location	Software
UAV1 Strive	Experiment Manager	UAV lab Room 228	CAE Strive
UAV1 Sensor	IR/EO Sensor Modelling	UAV lab Room 228	CAE Turret Simulation
UAV1 Visual	Sensor Image Generation	UAV lab Room 228	CAE Medallion-S
UAV1 RAP	RTI Data Recording and Playback	UAV lab Room 228	CAE RAP
UAV1 Comms	HLA Communications Systems	UAV lab Room 228	CAE Voice Encoding Software
GCS1 AVO	UAV air vehicle operator station	UAV lab Room 228	CDL VCS-4586 Apache Server, VLC for Sensor repeat to MPO
GCS1 MPO	UAV mission payload operator station	UAV lab Room 228	CDL VCS-4586 Apache Server for GCS repeater
GCS2 MPO	Streaming sensor view from GCS1	ACCES lab Rm 222	CDL VCS-4586 Apache Server for GCS repeater
FFSE-ML03	RTB 1 Crew Camera and Video Server	UAV lab Room 228	Helix server, Real Producer
FFSE-ML04	RTB 2 Crew Camera and Video Server	ACCES lab Rm 222	Helix server, Real Producer
FFSE-DS20	Composite Voice Capture and Audio Server	UAV lab Room 228	Helix server, Real Producer
FFSE-ACCS1	RTB 1 Crew Camera View	ACCES lab Rm 222	HTML viewer + VLC for video stream
FFSE-ACCS2	RTB 2 Crew Camera View + GCS map repeater	ACCES lab Rm 222	HTML viewer + Real Player for video stream
FFSE-DS11	Crew Camera View from Carleton	ACCES lab Rm 222	HTML viewer + Real Media + VLC for video stream
FFSE-DS05	Streamed Voice Receiver	ACCES lab Rm 222	HTML viewer + Real Player for audio

			stream
FFSE-DS19	Network monitor	Office 215	OPNET

5. Griffon Helicopter Simulation at Carleton University

5.1 General Overview

The flight simulator at Carleton University is a customized version of a Networked Tactical Simulator (NTS) developed as a result of the TAMSS (Tactical Aviation Mission Systems Simulation) TDP initiative, through funding provided by the Department of National Defence (DND). As with similar NTS systems, the Carleton NTS represents the flight deck, mission equipment, and physical structure of the CH-146 Griffon helicopter flown by DND. The Carleton simulator includes both out-the-window (OTW) and Helmet Mounted Display (HMD) capabilities. Additionally, the simulator supports the creation of synthetic environments and scenario creation via a collection of Commercial-Off-The-Shelf (COTS) software tools.

The Carleton NTS is unique in that it includes experimental and data collection capabilities. These experimental capabilities allow a user to create visual and auditory events that can be inserted into a mission. The data collection capabilities enable an experimenter to examine over 100 logged measures in analyzing the performance, workload, and situation awareness of the crew operating the simulator.

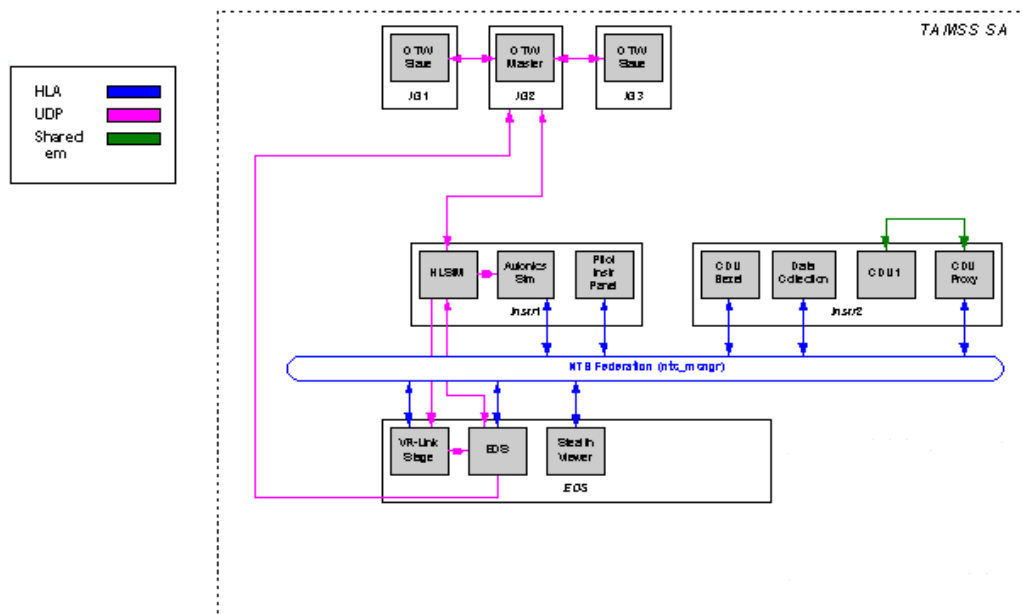


Figure 6 - Carleton University NTS Architecture Overview

The Carleton NTS consists of six PCs, running the Windows 2000 Professional operating system. Three of the PCs are used for image generation (IG1, IG2, and IG3) and simultaneously project onto three 8' x 6' screens, providing the pilot with a near 180-degree horizontal and 40-degree vertical view. Two PCs (INSTR1, INSTR2) are used for simulation of the flight model and instrumentation. INSTR1 is responsible for running the helicopter flight model (HELISIM), simulating the avionics, and for driving the pilot instrument panel. INSTR2 is responsible for the operation of the CDUs. The INSTR1 PC also hosts the custom data collection software used in the Carleton experiments. Finally, the sixth PC, the Experimenter/Operator Station (EOS), is responsible for overall system control, including mission loading and unloading. This PC also hosts the scenario generation software and a Stealth viewer. The simulator includes an ASTi Digital Audio Communications System (DACS) that supports simulation of cockpit voice communication as well as voice communication between the pilot and console operator. Data transfer between the various modules occurs via one of three modes. High volume data, such as that between the flight model software and scene generator, uses UDP communications. Communications between the avionics simulation, the pilot instrument panels and the CDU infrastructure is via high-level architecture (HLA). HLA is also used to interface the simulator to external systems. Finally, shared memory is used for communications between the CDU and the CDU Proxy, which facilitates integration of the non-HLA native CDU simulation into the NTS federation. Figures 6 and 7 provide a general overview of the hardware, functionality, and communications infrastructure of the Carleton NTS.

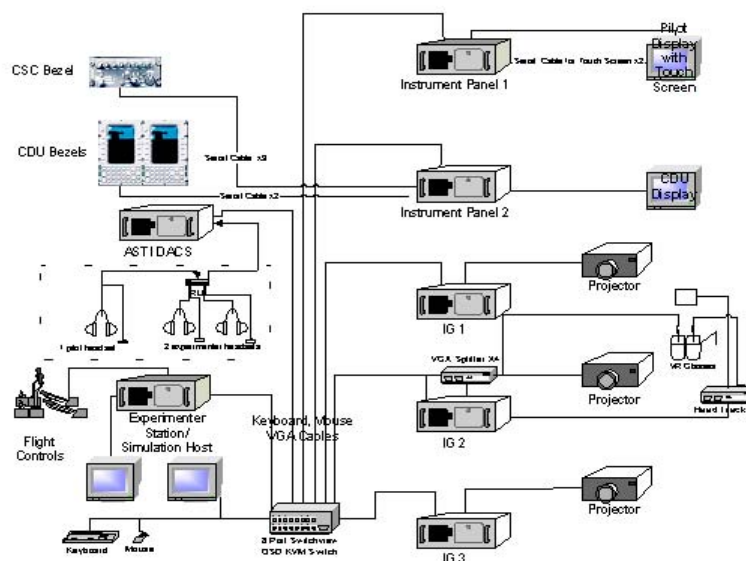


Figure 7 - Carleton University NTS Hardware Overview

5.2 Software Overview

The Carleton NTS software consists of several Commercial Off-the-Shelf (COTS) Software packages integrated by custom control, communications, and experimental software. The primary COTS products used and their function within the Carleton system are as follows:

Vega. Vega, a product from Multigen-Paradigm is the COTS tool used to render the Out the Window (OTW) or through the HMD external scene. Vega's strength is that it is able to render complex geometries in real-time. It is a key component in achieving visual realism in the simulation. It is ultimately based on the OpenGL 2D and 3D graphics application programming interface (API).

Vega uses Openflight (a 3D file format) models of both the terrain database and scene objects to render the scene. These entities are configured into the Vega application using the LynX graphical interface. This graphical interface is used to create Vega application definition files (.adf files). These files describe both graphical and platform related details of the Vega application. Vega renders the outside scene based on the graphical objects defined in the .adf files and a given "eye" point determined by the aircraft position and/or head position.

Vega also includes a development API that enables a user to customize Vega functionality for specific applications. For example, this API is used in the Carleton system to generate HUD information and symbology. Vega software callbacks are used to superimpose the HUD information on the Vega scene as seen through Night Vision Goggles (NVGs). The API has also been used to extend Vega capabilities to handle visual experiment events generated through the experimental software.

HELISIM. Helisim, from eNGENUITY Technologies, Inc, is a software package used to provide the flight model. HELISIM mimics the performance of a rotary-wing aircraft by tuning parameters such as weight and balance, propulsion and rotor characteristics, and instrumentation, thus enabling the simulator to closely represent the flight dynamics of the CH-146 Griffon. HELISIM accepts inputs from the collective, cyclic and pedals of the simulator and using the defined flight model, updates aircraft position (i.e., latitude, longitude, and altitude), aircraft heading, pitch, and roll as well as several other flight and instrumentation values.

An important feature of HELISIM is an API that allows for real-time control of various aircraft parameters. This is an extremely important feature for experimentation. Using these HELISIM features, the Carleton lab has developed a capability to freeze specific instrumentation (e.g., aircraft heading, radar altimeter, etc.). Pilots' situational awareness of their cockpit systems is measured using the freezing capability (e.g., did the pilot notice the frozen instrumentation, how long did it take for them to notice and react to the frozen instrumentation). The Carleton lab

has also used the HELISIM API to develop a capability to measure the control of aircraft position and orientation based on an ADS-33 attitude recovery task.

STAGE. STAGE is the acronym for Scenario, Toolkit and Generation Environment. It is a software tool used to create complex tactical scenarios. STAGE provides a graphical user interface in which to enter information into a tactical database. This database then generates the real-time tactical scenario. STAGE also displays the real-time positions of entities in the scenario as it is run on its situation display.

STAGE is used to add “entities” to the simulated mission scenarios. This STAGE entity information is sent to Vega, which renders the STAGE entities in the external scene in the appropriate position. The level at which the pilot detects the STAGE entities during the mission can be used to gauge the pilot’s level of situational awareness.

STAGE can be run in one of two modes – with HLA enabled or disabled. When HLA is enabled, STAGE becomes the HLA gateway for the entire system and can be used to send the STAGE entity (including Ownship) information to external agencies. When the STAGE HLA interface is not enabled, STAGE communicates only with local simulator components.

STEALTH. The MÄK Stealth viewer is a 3D visualization tool that extends the console operator's viewpoint of the simulated environment beyond the fixed point of the pilot to anywhere in the simulated world. Stealth enables the console operator to attach to other entities in the simulated environment to see the world through their eyes. Stealth receives its information on entity position from STAGE using the HLA interface.

5.3 Modifications to Support JSMARTS Experiment

A number of modifications were made to the Carleton NTS in order to support the participation in the JSMARTS experiment. These modifications were undertaken to ensure a proper correlation between the synthetic environments represented on each of the JSMARTS participant simulator platforms, thus promoting a “fair fight” between live participants and Computer Generated Forces (CGF). The following sections summarize the modifications made to the Carleton NTS in order to facilitate participation in the JSMARTS experiment:

5.3.1 Integration of CAE Medallion-S Image Generation System

The baseline Image Generation (IG) system of the Carleton NTS was upgraded to a CAE Medallion-S IG software running on COTS computer hardware. This was achieved through the addition of four rack-mounted PCs, each equipped with dual 3.0 GHz Pentium IV processors, 1 GB of RAM and

an ATI Radeon 9800 graphics card. Three of the PCs were configured as Medallion-S OTW visual channels. The fourth PC was configured as a Medallion-S Mission Information Function (MIF) platform. The MIF functionality was used to compute Height Above Terrain (HAT) in order to support the requirements of the HELISIM aerodynamic model.

The integration of the Medallion-S IG also involved the development of a software proxy application (IGProxy) that was used to mediate between the Interface Control Document (ICD) specification for Medallion-S and the HELISIM-based host simulation.

5.3.2 Federating the Carleton NTS with the JSMARTS Federation

A STRIVE plugin was developed to facilitate the federating of the NTS with the JSMARTS federation. This plugin was configured to receive host export information from HELISIM (i.e., aircraft Time, Space, Position Information (TSPI)) and represent the Carleton NTS as a simulation entity within the JSMARTS HLA federation. This plugin also provided an interface to HELISIM that allowed the Carleton NTS to comply with JSMARTS federation simulation management interactions, such as « Pause/Freeze » and « Start/Resume ». The support for these interactions was important in order to coordinate federation simulation assets.

6. Data records from the RTB at DRDC Ottawa

A comprehensive data set was gathered during the experiment, including all entity motion, STANAG 4586 message data (including commanded and actual positions of the UAV and camera sensors), voice communications, video footage, snapshots of the Global Command and Control Station recognized maritime picture and daily crew questionnaires.

The following sections discuss and provide examples of the quantitative data recorded. The audio and video files are in the attached CD, and identified by filenames, which include the date, mission and time.

6.1 Kinematic data

The RTB system has the capability to record missions, by storing all HLA data from the run-time infrastructure. This allows playback of the mission, but also allows decoding for data such as position, attitude, velocity, and acceleration of all STRIVE entities, including the UAV. After decoding, data associated with each STRIVE entity is time-stamped and recorded into a single file as in **Figure 8**. The first line of the Record and Playback (RAP) file contains a semicolon-separated list describing (in text) the contents of each field in each subsequent line. These files will be referred to as RAP data files herein. All fields and their associated data-type contained in the RAP files are listed in **Figure 9**.

AbsoluteTimeStamp	ClassType	AccelerationVector.mXAcceleration	AccelerationVector.mYAcceleration	AccelerationVector.mZAcceleration	AngularVelocityVector.mXAngularVelocity	AngularVelocityVector.mYAngularVelocity	AngularVelocityVector.mZAngularVelocity
EntityIdentifier.mEntityNumber	Orientation.mPhi	Orientation.mPsi	Orientation.mTheta	WorldLocation.mX	WorldLocation.mY	WorldLocation.mZ	VelocityVector.mXVelocity
VelocityVector.mYVelocity	VelocityVector.mZVelocity	mBodyLocation.mLat	mBodyLocation.mLon	mBodyLocation.mAlt	mBodyVelocityVector.mXVelocity	mBodyVelocityVector.mYVelocity	mBodyVelocityVector.mZVelocity
mBodyAccelerationVector.mXAcceleration	mBodyAccelerationVector.mYAcceleration	mBodyAccelerationVector.mZAcceleration	mBodyOrientation.mPhi	mBodyOrientation.mPsi	mBodyOrientation.mTheta	AbsoluteTimeStamp	ClassType
AccelerationVector.mXAcceleration	AccelerationVector.mYAcceleration	AccelerationVector.mZAcceleration	AngularVelocityVector.mXAngularVelocity	AngularVelocityVector.mYAngularVelocity	AngularVelocityVector.mZAngularVelocity	EntityIdentifier.mEntityNumber	Orientation.mPhi
Orientation.mPsi	Orientation.mTheta	WorldLocation.mX	WorldLocation.mY	WorldLocation.mZ	VelocityVector.mXVelocity	VelocityVector.mYVelocity	VelocityVector.mZVelocity
mBodyLocation.mLat	mBodyLocation.mLon	mBodyLocation.mAlt	mBodyVelocityVector.mXVelocity	mBodyVelocityVector.mYVelocity	mBodyVelocityVector.mZVelocity	mBodyAccelerationVector.mXAcceleration	mBodyAccelerationVector.mYAcceleration
mBodyAccelerationVector.mZAcceleration	mBodyOrientation.mPhi	mBodyOrientation.mPsi	mBodyOrientation.mTheta	AbsoluteTimeStamp	ClassType	AccelerationVector.mXAcceleration	AccelerationVector.mYAcceleration
AccelerationVector.mZAcceleration	AngularVelocityVector.mXAngularVelocity	AngularVelocityVector.mYAngularVelocity	AngularVelocityVector.mZAngularVelocity	EntityIdentifier.mEntityNumber	Orientation.mPhi	Orientation.mPsi	Orientation.mTheta
WorldLocation.mX	WorldLocation.mY	WorldLocation.mZ	VelocityVector.mXVelocity	VelocityVector.mYVelocity	VelocityVector.mZVelocity	mBodyLocation.mLat	mBodyLocation.mLon
mBodyLocation.mAlt	mBodyVelocityVector.mXVelocity	mBodyVelocityVector.mYVelocity	mBodyVelocityVector.mZVelocity	mBodyAccelerationVector.mXAcceleration	mBodyAccelerationVector.mYAcceleration	mBodyAccelerationVector.mZAcceleration	mBodyOrientation.mPhi
mBodyOrientation.mPsi	mBodyOrientation.mTheta	AbsoluteTimeStamp	ClassType	AccelerationVector.mXAcceleration	AccelerationVector.mYAcceleration	AccelerationVector.mZAcceleration	AngularVelocityVector.mXAngularVelocity
AngularVelocityVector.mYAngularVelocity	AngularVelocityVector.mZAngularVelocity	EntityIdentifier.mEntityNumber	Orientation.mPhi	Orientation.mPsi	Orientation.mTheta	WorldLocation.mX	WorldLocation.mY
WorldLocation.mZ	VelocityVector.mXVelocity	VelocityVector.mYVelocity	VelocityVector.mZVelocity	mBodyLocation.mLat	mBodyLocation.mLon	mBodyLocation.mAlt	mBodyVelocityVector.mXVelocity
mBodyVelocityVector.mYVelocity	mBodyVelocityVector.mZVelocity	mBodyAccelerationVector.mXAcceleration	mBodyAccelerationVector.mYAcceleration	mBodyAccelerationVector.mZAcceleration	mBodyOrientation.mPhi	mBodyOrientation.mPsi	mBodyOrientation.mTheta
252157	0	5.25E-05	-0.000116771	-5.93E-05	-0.032856759	0.000127096	-
0.000383347	60000	3.138170958	1.99312079	-0.455616295	1104191.308	-2457472.554	5776931.999
-2457472.554	5776931.999	-28.11977196	64.14194489	32.41397095	1.136980078	-1.148508121	1.3716.25606
77.1607303	0.638045226						

Figure 8. An example of the decoded RAP file for one entity.

field type	data type	units	frame
Time Stamp	int	μs	N/A
Class Type	int	N/A	N/A
Object Name	hexadecimal(4)	N/A	N/A
Acceleration	float(3)	m/s^2	NED
Angular Velocity	float(3)	1/s	body
Entity Identifier	int	N/A	N/A
(ϕ, ψ, θ)	float(3)	1	NED
Location	float(3)	m	“w.r.t. terrain origin”
Velocity	float(3)	m/s	NED
Marking Data	text	N/A	N/A
Latitude	float	1	w.r.t. Earth
Longitude	float	1	w.r.t. Earth
Altitude	float	m	w.r.t. Earth
Velocity	float(3)	m/s	body
Acceleration	float(3)	m/s^2	body
(ϕ, ψ, θ)	float(3)	1	body

Figure 9 Fields and data-types contained in the RAP data files. Data-types with parenthesis indicate vectors of length as specified.

6.2 NATO STANAG 4586 Messages

The STANAG 4586 is a “Standardisation Agreement” developed by NATO as a means for producing standard interfaces for UAV Control Systems (USC) for NATO UAV interoperability. It consists of a set of seventy messages, each containing several fields of information with a time-stamp used for bi-directional communications between a UAV and a GCS.

As with the RAP data, this data was time-stamped and stored in a file, which was later processed through CAE software and dumped into a text file. Some of this data overlaps with the RAP data.

As an example, STANAG 4586 message #5 is the “Inertial States” and contains, among other data fields, the UAV latitude, longitude, altitude, speed, acceleration, configuration. STANAG message #11 is the “Vehicle Steering Command” and lists the commanded altitude, speed, and heading given to the UAV from the GCS. Other important STANAG messages are the “Vehicle Operating Mode Command” (#10) and the “Loiter Configuration” (#62). A full listing of the messages and fields can be found in the Edition 2 of the STANAG 4586.

An example of a decoded STANAG 4586 data file is provided in Figure 10. There was one such file for each message type, for each mission.

AbsoluteTimeStamp;StanagType;StanagTimeStamp;mVehicleID;CUCSID;AltitudeCommandType;Com
 mandedAltitude;CommandedAltitudeRate;HeadingCommandType;CommandedHeading;CommandedHe
 adingRate;CommandedAirspeed;SpeedType;Waypoint;BarometricPressure;AltitudeType;LoiterPositionL
 atitude;LoiterPositionLongitude
 438427;11;1087584838.827497;168430081;305419894;1;2000;0;1;1.5920697450637817;0;0;0;1;0;0;0.8
 0047029137742798;-1.153215378882174
 438626;11;1087584839.007618;168430081;305419894;1;2000;0;1;1.8766752481460571;0;0;0;1;0;0;0.8
 0047029137742798;-1.153215378882174
 438838;11;1087584839.247849;168430081;305419894;1;2000;0;1;2.09686279296875;0;0;0;1;0;0;0.800
 47029137742798;-1.153215378882174
 439126;11;1087584839.4878221;168430081;305419894;1;2000;0;1;2.3561944961547852;0;0;0;1;0;0;0.
 80047029137742798;-1.153215378882174
 439342;11;1087584839.6699381;168430081;305419894;1;2000;0;1;2.7091848850250244;0;0;0;1;0;0;0.
 80047029137742798;-1.153215378882174
 439441;11;1087584839.7880659;168430081;305419894;1;2000;0;1;-
 3.0221636295318604;0;0;0;1;0;0;0.80047029137742798;-1.153215378882174
 439644;11;1087584840.0283141;168430081;305419894;1;2000;0;1;-
 2.7928216457366943;0;0;0;1;0;0;0.80047029137742798;-1.153215378882174
 439845;11;1087584840.2075579;168430081;305419894;1;2000;0;1;-
 3.0466408729553223;0;0;0;1;0;0;0.80047029137742798;-1.153215378882174
 440044;11;1087584840.448153;168430081;305419894;1;2000;0;1;-
 3.0466408729553223;0;0;0;1;0;0;0.80047029137742798;-1.153215378882174

Figure 10. Example of recorded STANAG 4586 Message Traffic

7. Observation /DEMO Lab used in the EXperiment

The main laboratory facilities used at DRDC Ottawa included the UAV Battle Lab (Rm. 228) and the ACCES lab (Rm. 222). The Advanced Collaborative Capability Engineering System (ACCES) lab is a state of the art Multi-Media Lab used for Live Demonstrations and VIP Observation. In the JSMARTS Live demonstration, an attempt was made to provide complete coverage of the distributed experiment from the observation site to allow observers to view all aspects of the experiment from one single location, thus maximizing situational awareness for all. An html page was created for the specific purpose of easily selecting any view from the web interface (see Fig. 7). The observations site included:

1. **A view of the Synthetic Tactical Environment, which would display** the current status of the synthetic environment as seen by the experiment manager station.
2. **Live camera feed of RTB 1 showed the** RTB operator crew.
3. **Live Electro-Optical (EO) and Infra-Red (IR) camera video feed from RTB 1** displayed the sensor views as seen on the Ground Control Station Mission Payload Operator (GCS-MPO) station. It contained a map of the current area of operation and an IR or EO sensor capture. This is refreshed every 10 seconds.
4. **Operator and Mission Crew Voice Communications:** All voice communications between the various operators and mission crew were recorded into a single channel, and transmitted live to the observation site in a live real media format.
5. **Live Video Feed from the Griffon Helicopter Simulator:** During the actual demonstration, some pre-recorded video of the Griffon simulator taking part in a mission scenario was fed into the ACCES Lab, since the live feed from Carleton was experiencing technical difficulties.

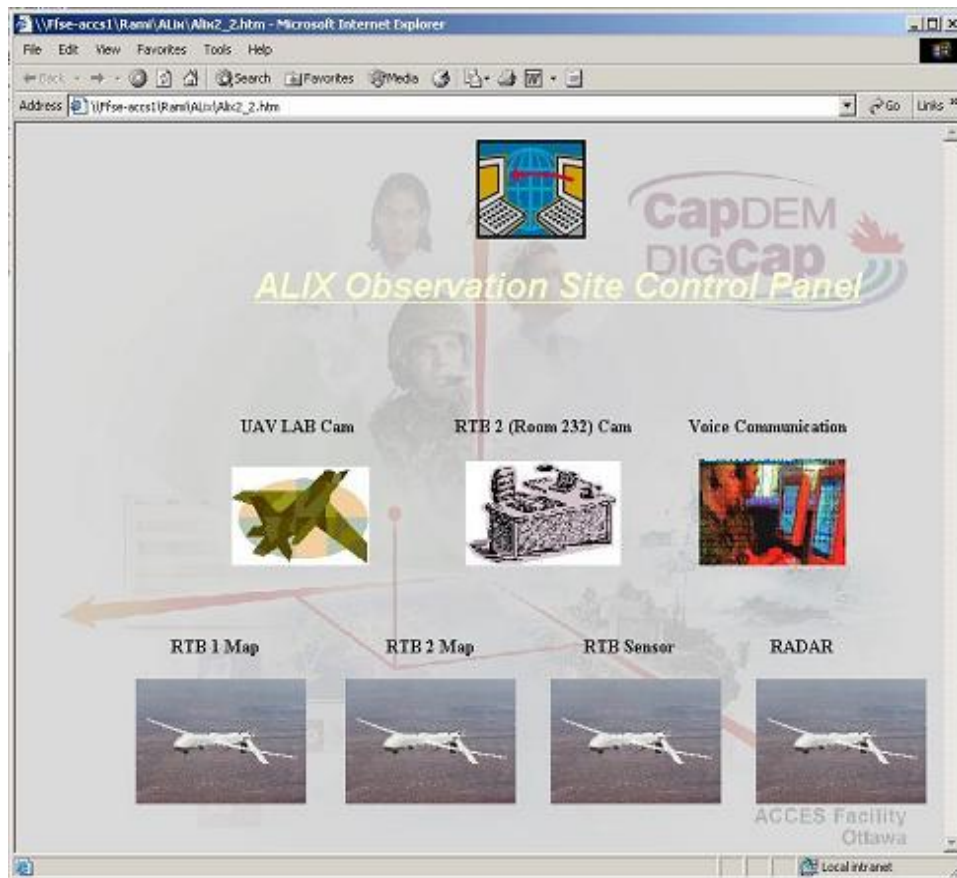


Figure 11: The WEB interface for the VIP Observation/Demo Lab. From this html page, all audio and video feeds could be accessed in the ACCES Lab, all supported by FFSE's JSIMNet network.

8. Conclusions and future work

The results of the present experiment have demonstrated that an interoperable HLA-based distributed simulation federation can be assembled and executed over a non-dedicated, unclassified, VPN-encrypted network in about 4 weeks. Though it may sound trivial to some, rarely has the GOC, Industry and Academia simulated together in Canada, and they certainly have never performed such an initiative in such a short period of time. It is also interesting to highlight that since such a simulation could be performed in this amount of time, this initiative was never a project or a program, it was nothing more than an initiative that simulationists executed as a JSMARTS concept.

From a technical perspective, this experiment has also demonstrated that it is possible to perform a distributed simulation using different FOMs and different RTIs, if the team is using a FOM Gateway to perform the re-mapping. Using the GENESA tool, the team members were able to avoid any development time associated with changing FOMs and acquiring another RTI. Further, additional development time, including ensuring perfect data correlation was cut by selecting STRIVE as a common SE tool.

Though it is still early, preliminary data seem to suggest that when the Tactical Aircrew have control of UAV sensors, in a Network Centric Warfare context, it leads to enhanced Griffon crew performance through an improved tactical effectiveness, increased situational awareness and decreased workload. Additional studies are required to confirm this finding.

Finally, it is possible to conclude that the achievement of HLA distributed simulation with GOC, Academia and Industry partners will lead to a further increment in critical mass of partners using simulation, using International standards, and thus enhancing the Return on Investment in M&S. Such an expansion of simulation utilisation with more partners joining in, each with their own SE capability, know-how, assets, etc., indicates that more re-usability will be available to the Canadian communities involved in any aspect of simulation, from CD&E to Training all the way to disposal of any system of capability. Such an increase in critical mass of Organizations utilizing M&S also means a larger Canadian capability to participate in CD&E and exploring “what if” scenarios of any kind. This includes CBRN threat assessments for Public Security partners that could be involved a Distributed Simulation prior to the Vancouver Olympics of 2010, as one example.

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List of symbols/abbreviations/acronyms/initialisms

ACCES	Advanced Collaborative Capability Engineering System
API	Application Programming Interface
AVO	Air Vehicle Operator
CD&E	Concept Development and Experimentation
CF	Canadian Forces
CFEC	Canadian Forces Experiment Centre
CGF	Computer Generated Forces
COTS	Commercial-Off-The-Shelf
DACS	Digital Audio Communications System
DAR	Director Aerospace Requirements
DIS	Distributed Interactive Simulation
DRDC	Defence Research and Development Canada
DND	Department of National Defence
EO/IR	Electro-Optical and Infra-Red Sensor
EOS	Experimenter/Operator Station
FEDEP	Federation Development and Execution Process
FFSE	Future Forces Synthetic Environments
FOM	Federation Object Model
GCS	Ground Control Station
GOC	Government of Canada

HAT	Height Above Terrain
HLA	High Level Architecture
HMD	Hemet Mounted Display
ICD	Interface Control Document
IG	Image Generation
JSIMNet	Joint Simulation Network, FFSE
JSMARTS	Joint Simulation, Modeling for Material Acquisition, Requirements, Training, and Support
M&S	Modeling and Simulation
MIF	Mission Information Function
MPO	Mission Payload Operator
NTS	Networked Tactical Simulator
NVG	Night Vision Goggle
OGD	Other Government Department
OTW	Out-The-Window
RAP	Record and Playback
RPR FOM	Real-time Platform Reference Federation Object Model
RTB	Research Test Bed
RTI	Run Time Infrastructure
SE	Synthetic Environment
SMARRT	Simulation and Modeling for Acquisition, Requirements, Rehearsal and Training
SME	Subject Matter Expert
STANAG	Standardisation Agreement (NATO)

TAMSS	Tactical Aviation Mission Systems Simulation
TDP	Technology Demonstration Program
TSPI	Time, Space, Position Information
UAV	Uninhabited Aerial Vehicle
WAN	Wide Area Network
v_c	UAV velocity vector
W_5	wind victor
	heading
θ_w	wind heading
	standard deviation

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JSMARTS, or Joint SMARRT represents a new concept for DND, it is conceptualized as a vision of M&S at the Enterprise level, led by ADM(Mat). In an effort to reduce the technical risk associated with networking simulation stakeholders at various levels of the DND Enterprise, a Wide Area Network (WAN) Distributed Simulation was executed, regrouping in the same virtual environment (Synthetic Environment) the Government of Canada, Industry and Academia. In this HLA Federation, the national Canarie Network was selected as the common, non-dedicated, unclassified, VPN-encrypted network procuring connectivity between Federates. While CAE Inc was providing Computer Generated Forces (CGF), DRDC Ottawa's FFSE Section was providing a UAV high fidelity simulator, a NATO STANAG 4586 compliant Ground Control Station, both supported by the Joint Simulation Network. (JSIMNET: FFSE's persistent simulation capability). Finally, Carleton University provided a CH 146 NTS Griffon hi-fidelity human-in-the-loop simulator. DAR graciously provided pilots, whereas the UAV aircrew was graciously provided by CFEC. To reduce at a bare minimum FEDEP development time, different FOMs and different RTIs were used but bridged by a remapping middleware tool. Finally, since a common SE tool STRIVE, existed amongst participants, it was used across all Organizations, further simplifying development time. CH146 NTS pilots and UAV Aircrew were engaged in 3 separate experimental conditions while human performance measurements were collected. This document provides a technical summary of the technical issues directly related in the successful execution of the present Exercise.

This study has demonstrated a successful case of interoperable HLA-based Distributed Simulation across Government, Industry and Academia. Further, this study suggest that harmonization, coherence and alignment with international standards, international protocols as well as common tools etc, ensured quick reusability of the existing simulation capability in the participating Organizations, for maximum interoperability.

14. KEYWORDS, DESCRIPTORS or IDENTIFIERS (technically meaningful terms or short phrases that characterize a document and could be helpful in cataloguing the document. They should be selected so that no security classification is required. Identifiers such as equipment model designation, trade name, military project code name, geographic location may also be included. If possible keywords should be selected from a published thesaurus. e.g. Thesaurus of Engineering and Scientific Terms (TEST) and that thesaurus-identified. If it is not possible to select indexing terms which are Unclassified, the classification of each should be indicated as with the title.)

Distributed Synthetic Environment; Government; Industry; Adademia; HLA; RTI, FOM; Simulation Network

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