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D-SAFIRE: A Distributed Simulation

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Abstract

Defence Research and Development Canada (DRDC) has been developing a low cost means to evaluate the integration of new display equipment for the Air Force. The result has been the Aircraft Crewstation Demonstrator (ACD), which is capable of simulating the cockpit of an aircraft for human factors evaluation (HFE). In order to support future display upgrades within the cockpit of the CF-18, DRDC contracted an HFE study of the CF-18 displays, especially the radar displays associated with radar and data link. Earlier work at the Defence Research Establishment Ottawa (DREO) had resulted in a high fidelity simulation of the air to air modes of a fighter radar. In order to develop as representative display as possible, a task to integrate the ACD with the DREO radar simulation as a distributed simulation was included with the HFE study. This report describes the use of the high level architecture (HLA) to combine these two disparate simulations into one distributed simulation. The results indicate that HLA is an effective means of combining different models to provide an improved simulation to the user. Advantages and limitations are discussed, as is a proposed future architecture.

Résumé

Recherche et Développement pour la Défense Canada (RDDC) ont développé une façon peu coûteuse d'évaluer l'intégration d'écrans de présentation pour les Forces Aériennes du Canada. Il en a résulté un simulateur de poste de pilotage d'avion pour l'évaluation de facteurs humains qui a pour nom le Aircraft Crewstation Demonstrator (ACD). Dans le but de supporté l'ajout de nouveaux écrans radars pour le CF-18, RDDC a contracté une étude portant sur l'évaluation des facteurs humains en focalisant principalement sur les écrans affichant l'information provenant du radar et du Data Link. Des travaux précédents conduit au Centre de Recherches pour la Défence, Ottawa (CRDO) ont résulté en un simulateur fidèle des modes air-air d'un radar d'avion de chasse. Dans le but de développer une présentation des plus réalistes, l'intégration de l'ACD et du simulateur radar de CRDO a aussi été incluse dans l'étude portant sur l'évaluation des facteurs humains. L'utilisation de l'architecture de haut niveau (HLA) dans le but de combiner les deux types de simulations en une seule simulation distribuée est discutée dans ce rapport. Les résultats démontrent que l'architecture HLA est un moyen efficace de combiner différents types de modèles afin d'améliorer une simulation par rapport à l'utilisateur. Les avantages et restrictions y sont discutés en plus d'y proposer une nouvelle architecture pour des utilisations futures.

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Executive Summary

Defence Research and Development Canada has been developing various capabilities to support the modernization of the CF-18. DREO has developed a high fidelity radar simulator, SAFIRE, for the CF-18, while DCIEM has been responsible for the development of the air crewstation demonstrator (ACD) that is capable of simulating the cockpit of an aircraft to facilitate human factor studies for the CF-18. This project summarizes the merging of these two capabilities into a single distributed simulation using the high level architecture (HLA) developed by the US Defense Modelling and Simulation Organization.

The development of the distributed simulation was one of the tasks of a human factors evaluation of prototype displays for the CF-18 aircraft. These prototype displays were to demonstrate the inclusion of new capabilities to the cockpit in order to improve operator effectiveness. The purpose of the distributed simulation task was to provide a validated radar model to a human-in-the-loop simulation while demonstrating the ability of such a legacy simulation to be integrated into a larger system. The various hardware and software components of the cockpit simulation and radar model are described. The design of the simulation interfaces of these components was accomplished using the HLA methodology and consisted of the creation of a federation object model to describe all of the interactions. The implementation of the federation is discussed along with a summary of the difficulties encountered during the implementation and integration phases. This includes some of the compromises that had to be used to achieve system operation in the time provided for the project.

Overall, the demonstration of the distributed simulation was successful. The SAFIRE radar model was used in 26 of the 32 test scenarios, and the resulting performance of the total simulation was praised by the operators. This task demonstrated that the effort to include a high fidelity legacy sensor model into a distributed simulation is relatively minor when the sensor model is designed in a modular fashion and the HLA runtime infrastructure is used. It also demonstrated that some high fidelity models should be avoided due to the runtime limitations typical of these systems. Future work with human-in-the-loop simulations are recommended to use simpler representative sensor models. The results have also demonstrated that it should be possible to create a complete missile engagement simulation using a federation consisting of current aircraft, radar, electronic support measures, electronic counter measures, missile seeker and missile models.

Geling, G.; Williams, C.; Guirguis, M. 2001. D-SAFIRE: A Distributed Simulation. DREO TM 2001-151. Defence Research Establishment Ottawa.

Sommaire

Dans le but de supporter la modernisation du CF-18, différentes capacités ont été développés par Recherche et Développement pour la Défense Canada (RDDC). Un simulateur radar de haute fiabilité, SAFIRE, a été conçue au CRDO alors que IMED était plutôt responsable du développent du simulateur Aircraft Crewstation Demonstrator (ACD) modélisant un poste de pilotage d'avion dans le but de faciliter l'étude des facteurs humains dans le CF-18. Ce projet résume la fusion de ces deux technologies en une seule simulation distribuée utilisant l'architecture de haut niveau (HLA) conçue l'Organisation de la Modélisation et Simulation de la Défense des Etats-Unis.

Le développement de cette simulation distribuée est une des tâches faisant partie de l'évaluation d'écrans de présentation prototypé pour le CF-18. Ces écrans de présentations prototypés ont pour but de démontrer l'inclusion de nouvelles capacités au poste de pilotage afin d'améliorer l'efficacité de l'opérateur. L'objectif de la tâche basée sur la simulation distribuée est d'introduire un modèle radar valide à une simulation de types " humains dans la boucle " tout en démontrant les possibilités d'inclure une simulation plus âgée dans un système de large envergure. Les diverses composantes logiciels et matériels du simulateur de poste de pilotage ainsi que du modèle radar y sont ici présentés. Les interfaces de simulations associées à ces composantes ont été conçues en se basant sur la méthodologie HLA ce qui a consistés à la création d'une fédération de modèles décrivant toutes les interactions entre les objets. L'implantation de la fédération d'objets y est discutée, de plus, une description sommaire des problèmes rencontrés dans la phase d'implantation et d'intégration y est présentée. Ce dernier point inclut les compromis utilisés afin d'obtenir un système opérationnel à l'intérieur du temps alloué à ce projet.

Dans l'ensemble, les démonstrations de simulations distribuées ont été accomplies avec succès. Le modèle radar SAFIRE a été utilisé dans 26 des 32 scénarios de test et les performances résultantes de la simulation globale ont été fortement appréciées par les opérateurs. Cette tâche a démontré que l'effort nécessaire afin d'inclure un modèle de capteur plus âgé dans une simulation distribuée est relativement minime lorsque que le modèle de capteur est conçu dans une approche modulaire et que l'infrastructure HLA est utilisée. Elle a aussi démontré que l'utilisation de modèles de capteurs de très grandes fidélités doit être proscrite étant donné leurs limitations en temps d'exécution. L'utilisation de modèle de capteurs simplifiés est recommandée pour de futures simulations de types " humains dans la boucle ". Les résultats ont aussi démontré qu'il devrait être possible de créer une simulation complète d'un engagement de missile utilisant sur une fédération comprenant l'avion actuel, le radar, les mesures de soutient électronique, les contre-mesures électroniques ainsi que des modèles de missiles et de missiles chercheurs.

Geling, G.; Williams, C.; Guirguis, M. 2001. D-SAFIRE: A Distributed Simulation. DREO TM 2001-151. Centre de Recherches pour la Défense Ottawa.

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1. Project Overview

1.1 Introduction

The Department of National Defence has been considering the upgrade of the avionics of the CF-18 fighter aircraft. Two main areas of improvement in the aircraft will be the upgrade of the APG-65 radar to the APG-73 radar and the inclusion of an improved data link capable of downloading target information to the CF-18 from external sources. Defence Research and Development Canada (DRDC) has been developing a low cost means to evaluate the integration of new display equipment for the Air Force. The result has been the Aircraft Crewstation Demonstrator (ACD), which is capable of simulating the cockpit of an aircraft for human factors evaluation (HFE). This capability was initially developed to evaluate a missile approach warning system interface (MAWS) for the CH-146 helicopter [1]. In that project, the ACD was integrated with missile simulation and detection equipment to provide realistic sensor performance to the operators. The technology developed in the MAWS program is transferrable to other aircraft, such as the CF-18. To support the expected display upgrades in the cockpit of the CF-18, DRDC contracted an HFE study[2] to develop and evaluate an upgraded air crew interface for the radar.

One of the objectives of the HFE study was to establish a functioning rapid prototype capable of interacting with existing third-party radar models. Earlier work at the Defence Research Establishment Ottawa (DREO) had resulted in a high fidelity simulation of the air-to-air modes of a fighter radar [3] . The DREO Simulator for advanced fighter radar EPM (SAFIRE) had originally been developed to display the interaction between the operator and the radar in an EW environment in as realistic and timely a manner as possible. In order to develop as representative a display as possible, a task to integrate the ACD with the DREO radar simulation as a distributed simulation was included with the HFE study. The work on this contract was to take advantage of the experience gained with the MAWS simulation. The ACD and the radar model would be implemented at separate facilities and interact via the DMSO high level architecture (HLA). The resulting distributed simulation would provide the cockpit experience at the contractor's facility while the detailed radar models would run at DREO.

This report describes the development of the various simulation components and the use of HLA to combine these two disparate simulations into one distributed simulation. The remainder of this chapter describes the initial hardware and software configurations that the simulation was built on. Chapter 2 discusses the various analysis carried out and the resulting design decisions. Chapter 3 summarizes the implementation and integration phase and Chapter 4 presents the results and conclusions. In general, the results indicate that HLA is an effective means of combining different models to provide an improved simulation to the user but that such simulations require detailed expertise when creating the user interface.

1.2 Software Architecture

The distributed simulation can be divided into three major software components. These components consist of the Aircraft Crewstation Demonstrator (ACD), the distributed version of the "SAFIRE APG-65 Radar", and the Run Time Infrastructure (RTI). A diagram of the distributed software objects and communication between the objects can be seen in **Figure 1**.

The Air Crewstation Demonstrator consists of two components. The "CF-188 ACD" and the "ACD Simulation Environment". The "CF-188 ACD" simulates the environment of the cockpit and the flight dynamics of the aircraft simulated for the pilot. The software component consists three components, the graphical display environment, a mission computer simulation and a flight simulator. The flight simulator is a commercial off-the-shelf (COTS) product, FLSIM, and provides a real time, high-fidelity simulation of the flight characteristics and handling of any fixed wing aircraft (The CF-18 in this case). It translates the inputs received from the user interface into changes in the flight profile of the CF-18. The mission computer simulation is

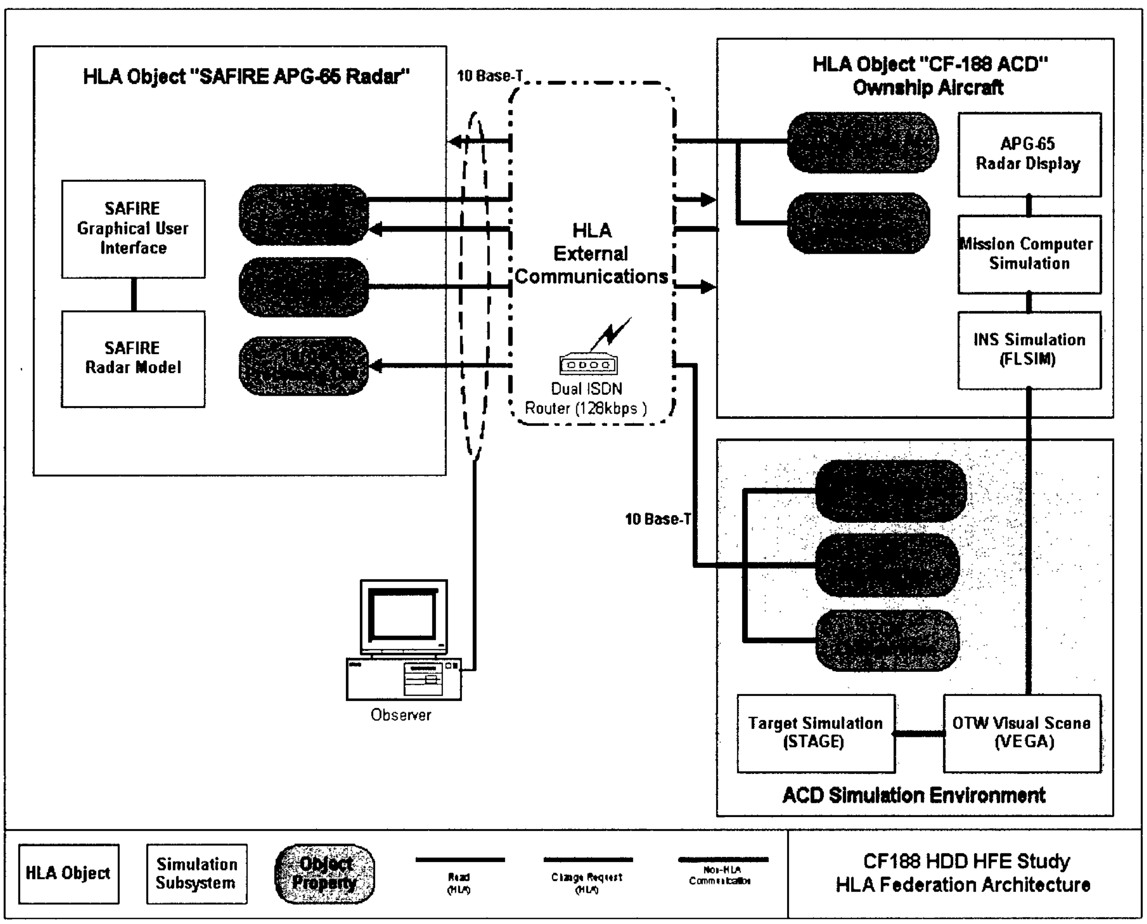

Figure 1 Distributed simulation software architecture

used to control the interface between the flight simulation and the radar simulation and display. The internal displays and controls of the CF-18 are generated and interfaced to the flight simulation through the use of the COTS tool, VAPS. This tool is designed to assist the developers in quickly creating new prototype displays. The other component of the ACD is the "ACD Simulation Environment". This component controls the simulated environment outside of the aircraft being simulated for the pilot. This environment is maintained by another COTS software tool, STAGE. STAGE (Scenario Toolkit And Generation Environment) is used to build and animate, in real-time, a synthetic environment that may contain both moving and stationary entities such as airplanes, ships, land vehicles, missiles, and radar sites. The simulated external environment is created by the VEGA program. VEGA generates the visual scenes for presentation to the pilot on three projection screens. These entities interact with one another either as a function of pre-determined rule sets or through operator intervention during execution of the simulation. This provides a development framework for aerospace and defence simulation and training applications. The targets in the tactical scenarios are all configured to act via the rule sets, and the operator interaction is provided for the piloted CF-18 via integration with FLSIM.

The "SAFIRE APG-65 Radar" component is a high fidelity radar simulation. SAFIRE was developed by the Aerospace Radar and Navigation section of DREO to simulate air-to-air modes of the radar for the CF-18 in electronic warfare environments. SAFIRE generates the radar returns for all simulated targets, electronic counter-measures, and generic ground clutter and processes them using algorithms similar to those used in the APG-65. The air-to-air modes implemented in the current version of SAFIRE include the Range-While-Search (RWS) modes, the Track-While-Scan (TWS) modes and the monopulse single target track (STT) modes. The results of the radar processing are then presented on a display in the format that the operators are familiar with as shown in **Figure 2**. The SAFIRE simulation, while very complex, was still capable of running un-altered for one target at approximately five times real time. For example, the SAFIRE requires five seconds to run through one second of simulated time. Additional targets or jamming techniques reduce the run time performance. The project plan was to create a modified version of the SAFIRE program, D-SAFIRE, to run in real-time as part of a distributed simulation.

All of the information between the radar simulation and the cockpit simulation are regulated by the HLA communications protocols. The HLA is a framework developed by the United States Department of Defence, Defence Modelling and Simulation Office (DMSO) that supports distributed simulations by defining an interface between the distributed components. The HLA interface specification defines a Run Time Infrastructure (RTI) which is the component of the distributed simulation that provides the implementation and encapsulation of the communication protocols defined in the HLA specification. The RTI implementation handles the communication between the simulation components while hiding the details of the how the communication is achieved. HLA describes a distributed simulation as a federation and all of the simulation participants as federates. HLA RTI 1.3 has received status as an IEEE standard (IEEE 1516, 1516.1, 1516.2) and the interface specification is described in [4].

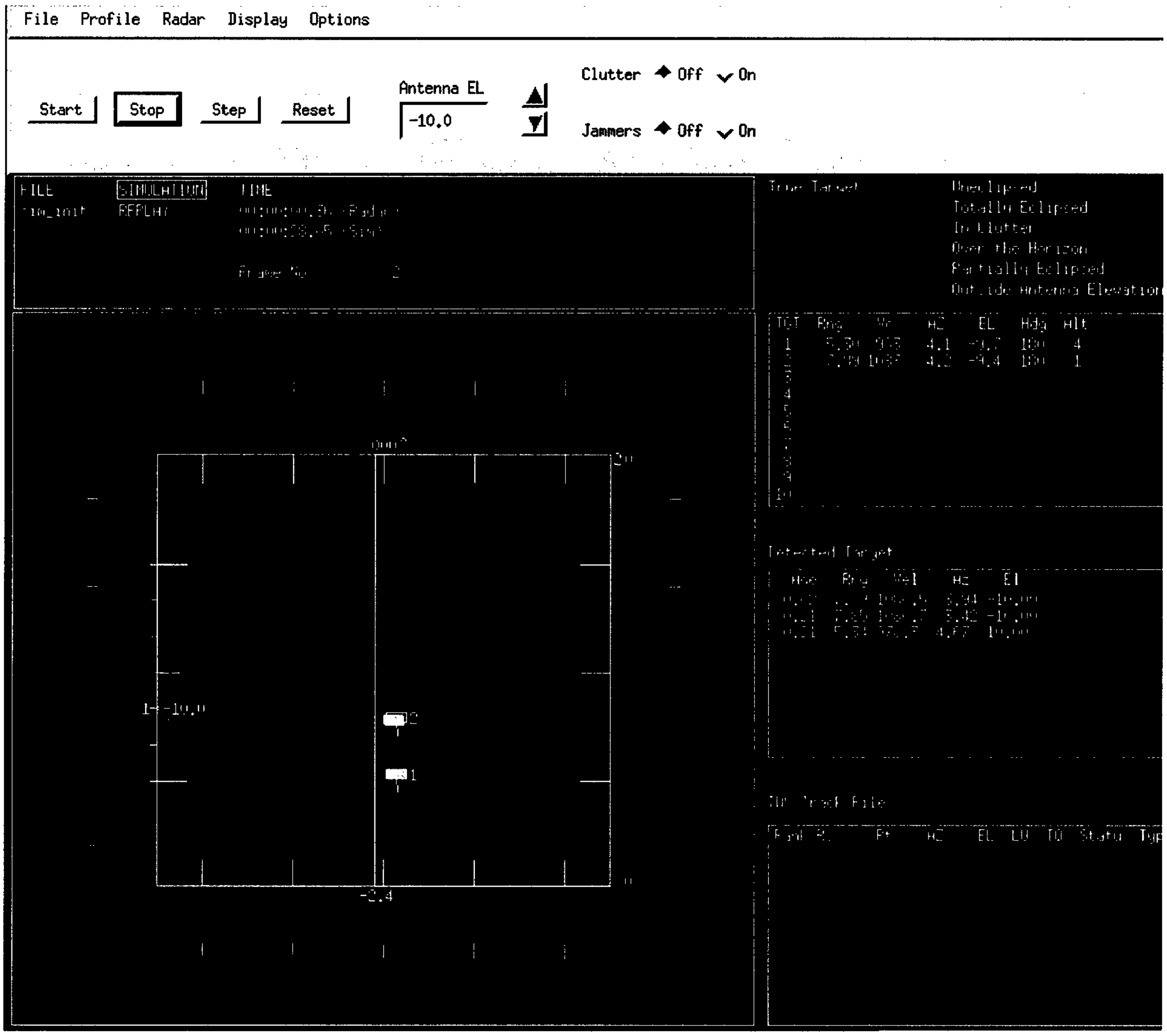

Figure 2: SAFIRE Graphical User Interface.

The HLA components that come from DMSO are the RTIexecutive and fedex programs. These programs are essential to operation of the distributed simulation. The RTIexecutive program is contacted by all simulation components when they join the simulation. When a simulation federation is started the RTIexecutive starts a fedex process to manage the federation. When a simulation federate joins a federation a connection is established between that federate and all other federates in the simulation. Establishing and managing the connections is accomplished by the RTI objects that come as part of the HLA implementation from DMSO.

1.3 Hardware Architecture

The network configuration of the hardware used for the distributed simulation is illustrated in **Figure 3**. The D-SAFIRE and ACD components were located at physically separate sites. As in the MAWS trial, ISDN protocols were used to connect the two sites. The two ISDN routers were the only points of communication between the machines at the CMC and DREO sites

D-SAFIRE was implemented on Schroeder, a SUN workstation with the Solaris 2.7 operating system. Schroeder was located at DREO. During the simulation Schroeder was connected via a 10 Base-T line to a router at DREO, which communicated with the router at CMC. During the simulations Schroeder was removed from the Local Area Network (LAN) at DREO. This ensured the security of the DREO LAN and guaranteed that Schroeder would be dedicated to running the D-SAFIRE program.

The DREO router communicated with a router at CMC using a dedicated ISDN line. The dedicated ISDN line between CMC and DREO was used to eliminate possible problems with network congestion during the simulation. The dedicated line also provided a means to connect the systems at CMC and DREO without dealing with the corporate firewalls while maintaining security for the simulation. The ISDN line provided 2 channels, each with a bandwidth of 64Kbps. The connection between the CMC router and the ACD used a 10 Base-T line. The details of the network configuration can be seen in Annex A.

The ACD components were located at CMC Electronics in their Human Factors Engineering (HFE) lab. The ACD environment consisted of, three SGI workstations and an Intel PC. The Intel PC was used to generate the sound effects for the simulation. The SGI workstations are labelled Onyx 1 & 2 and Octane. Communication between workstations at CMC was done using User Datagram Protocol (UDP) connections over a local area network in the HFE lab. A photograph of the ACD cockpit is given in **Figure 4**.

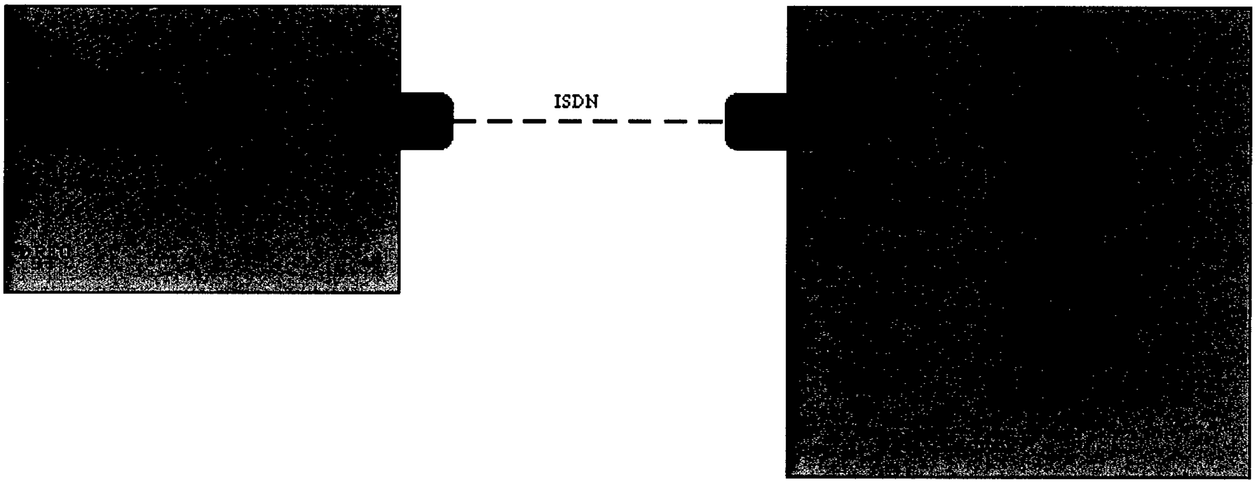

Figure 3: Distributed Simulation Hardware Configuration

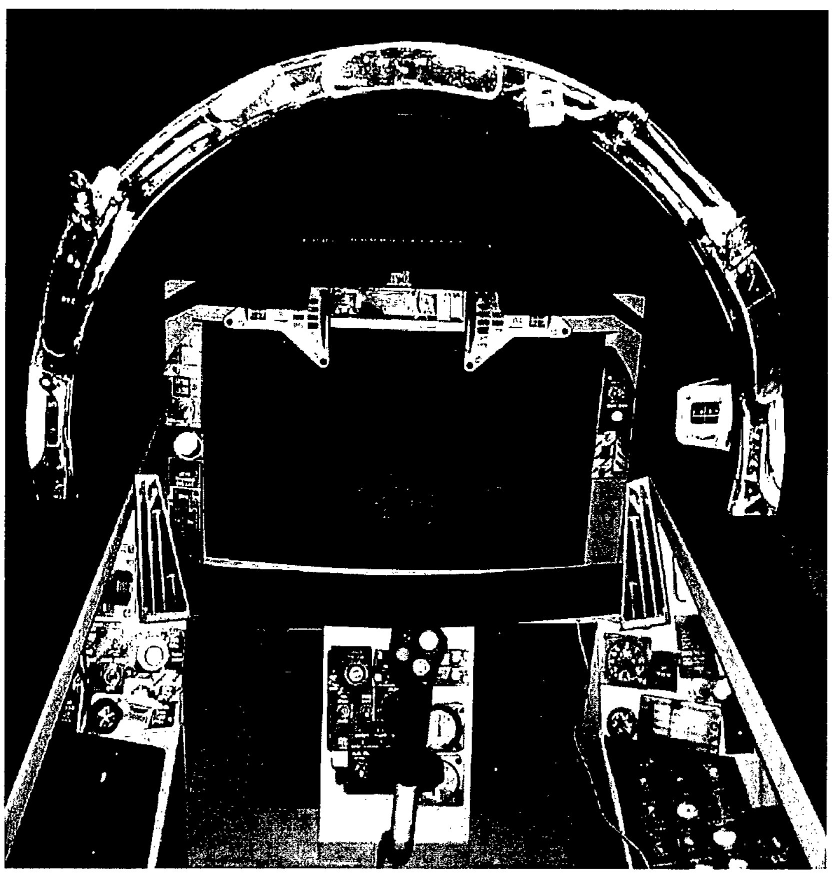

Figure 4: ACD Cockpit

2. Simulation Analysis and Design

This section presents the design done for the distributed simulation. As part of the HLA design method a Federation Object Model (FOM) for the simulation was developed. The development of the FOM is summarized in section 2.1. Following the summary of the FOM, a discussion of the issues involved in integrating the HLA interface with SAFIRE and the ACD is presented in sections 2.2 and 2.3.

2.1 Generation of the Federation Object Model

In accordance with the HLA specifications, the federation must be described by a FOM. The FOM defines who will be in the simulation, what information will be exchanged and how the information is represented. This task was completed by VPI and documented in the D-SAFIRE Federated Object Model report [5]. The specification of the FOM was based on what information SAFIRE would need to perform it's core function (i.e simulate the radar for the CF-18 (APG-65)) and what would be needed by the ACD to integrate the results with the cockpit displays. During the development phase CMC was consulted and their input was integrated with the FOM. The FOM was submitted to DREO and CMC for review and approval before any detailed design and implementation work began.

The FOM for this simulation consists of five control interactions and four data passing interactions between the ownship aircraft and radar sensor objects. These are listed in **Table 1** with the indication for each object of which signals can be initiated and which must respond. The control signals consist of two signals to start and stop the radar simulation (Create Radar Object, Destroy Radar Object), two signals to control the processing of current flight dynamics by the radar simulation (Radar Pause Request, Radar Continue Request) and a final signal to indicate the end of the simulation. The four data interactions convey the latest target information (Update Target Processing List), ACD information (Update Aircraft), the Radar Parameters to use in the simulation and the radar detections (Radar Status Report).

The Update Target Processing List consisted of the range, radial velocity and acceleration, azimuth and elevation relative to the ACD for each target in the list. In addition to the flight dynamics of the target aircraft, the radar cross section and radar cross section model to be used in the simulation were also sent for each target. A flag to indicate the use of a jammer by a target aircraft was also included as part of the target update.

The Update Aircraft interactions contained a Time Space Position Indicator (TSPI) for the ACD as well as the weapon configuration. The TSPI contained the latitude, longitude and altitude of the ACD as well as the velocity and acceleration in (North, East and Down coordinates).

Interaction Classes	Ownship Aircraft	Radar Sensor	Description
Terminate Simulation	I	R	Signals D-SAFIRE to halt operation completely and shut down
Create Radar Object	IR	IR	Start and initialize D-SAFIRE
Destroy Radar Object	IR	IR	Terminate the current D-SAFIRE session
Radar Pause Request	IR	IR	Pause required for debugging purposes
Radar Continue Request	IR	IR	Continue required for debugging purposes
Update Aircraft	I	R	Motion model updates for ownship aircraft
Update Target Processing List	I	R	Motion model updates for target aircraft
Radar Parameters	IR	IR	Requests changes in the radar configuration, ie. Mode change
Radar Status Report	R	I	Results of last radar processing interval.

Table 1: Interaction Classes used to implement the radar federation.

The Radar Parameter interaction is used to communicate the operating conditions of the radar between the ACD radar and D-SAFIRE. This interaction contains the radar azimuth and elevation centre, the azimuth scan range, the current operating mode and the current azimuth and elevation of the radar antenna. The definition of the FOM was defined assuming that only the search modes would initially be implemented. There were additional fields defined in the interaction to support acquisition and tracking modes. These fields were not used in this simulation and are not detailed here. More detailed information about can be found in the D-SAFIRE Federation Object Model report.

The Radar Status Report generated by SAFIRE is used to communicate to the ACD the location of any detections from the most recent processing interval. The status report contains the range, closing velocity, azimuth and elevation of the detection. The status report also contains a values to indicate what kind of detection was made, the quality of the detection and an estimate of the target that generated the detection.

From the FOM a federation execution details (fed) file is generated. This is a text file that defines at a high level what can be exchanged between federates in the simulation. This file is used at run time by the RTI objects when communicating between federates. The file used for the SAFIRE simulation has been included as Annex B. The federation execution details file was generated by the Object Model Development Tool (OMDT) provided by DMSO.

Once the FOM was specified, the design of the ACD and D-SAFIRE modules began. The details of integrating the HLA module with SAFIRE are in the next section. Section 2.3 discusses the integration of the HLA module with the ACD.

2.2 HLA Integration with SAFIRE

The integration of the radar model with a human-in-the-loop distributed simulation required a number of modifications to the original SAFIRE program. One important requirement was the ability of the radar model to respond in realtime. The other was to ensure that the modified SAFIRE program interacted properly with the ACD federation. A detailed software design document [6] was developed for modifying the existing SAFIRE program to participate in the distributed simulation. The resulting modified program is referred to as D-SAFIRE. Throughout the implementation phase, the software design document was synchronized with the actual implementation.

At the start of this project, the SAFIRE program ran from three times to one hundred times slower than real-time, depending on simulation options. Prior to modifying SAFIRE to add HLA components, software optimizations were done to SAFIRE and hardware upgrades were applied to the Schroeder workstation. The details and results of the upgrades are documented in the SAFIRE Performance Enhancements Technical Note, Update [3]. The optimizations allowed the Scientific Simulation Software in SAFIRE to operate in realtime while simulating up to four targets. Several components of the simulation had to be selected off. The most intensive component of the simulation, the calculation of radar returns from the surface of the earth, had to be turned off for the realtime simulation. Once the optimizations and upgrades were done, work began on the implementation of modifications to SAFIRE required to support the HLA components.

The existing SAFIRE program consisted of two major components, the Scientific Simulation Software (SSS), and the graphical user interface (GUI). The RTI communications for the simulation were created as a separate component that was placed between the current GUI and SSS components. This required only minimal changes to the GUI portion of the simulation. The resulting radar model is shown in **Figure 5**. In order to allow the possibility of multiple restarts of the radar model during the simulation, a parent SAFIRE federate was used to start and stop the D-SAFIRE radar model. The implementation began by the adding the control signals in the FOM to SAFIRE. The control signals could be easily tested and verified. The implementation proceeded to add the ability of sending the radar detections to other members of the federation. The final phases of implementing HLA modifications to SAFIRE involved making parameter changes in the radar based on received HLA communication requests and inserting the latest flight dynamics into SAFIRE for simulation. The final configuration of the RTI communications between the federates in the distributed radar simulation is illustrated in **Figure 6**. The distributed operation of SAFIRE was thoroughly tested before integration with the ACD was attempted.

Implementation was aided by the development of two test programs; a Test Stub and an Observer. The Test Stub program generates the necessary interactions to test the behaviour of D-SAFIRE and replaces the ACD components of the simulation for testing. The Test Stub sends RTI communications that have been saved in a file. The Observer program was developed to observe all the communication in the federation and verify what was being communicated. The two test programs used the same architecture as D-SAFIRE so very little additional time was needed to implement these programs.

During testing of the modifications to SAFIRE, it was discovered that the added time to maintain the GUI caused the program not to operate in realtime. The GUI was made optional as a compile time constant, as a compromise to the existing SAFIRE program, in order to achieve real time operation. However, a separate version of D-SAFIRE with the GUI was created in order to facilitate debugging and demonstrations. With some additional optimizations of the code that interfaced with the RTI, D-SAFIRE did operate in real time for the simulation.

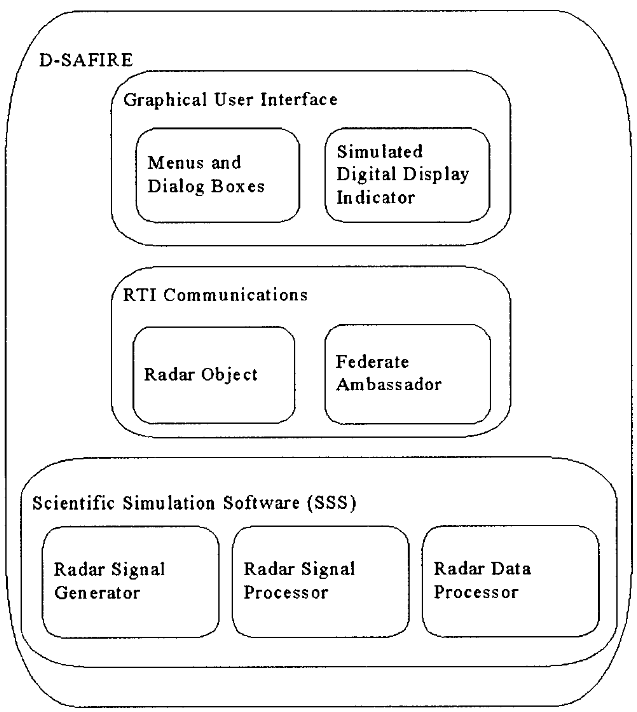

Figure 5: D-Safire software components.

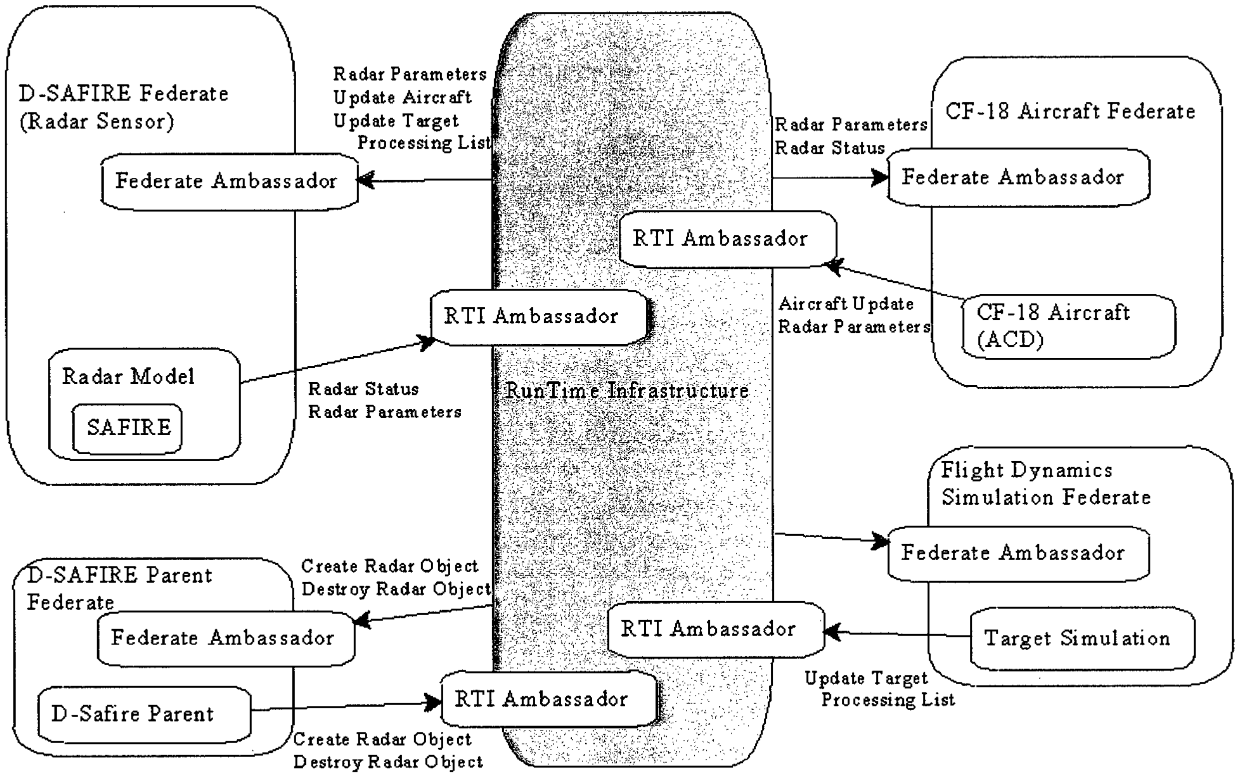

Figure 6: Model of ACD Federation RTI Communications

2.3 HLA Integration with ACD

The integration of the ACD with the radar model via the HLA framework, required collecting all of the relevant information from the different programs. Both the FLSIM and STAGE programs were running on the Onyx 1 workstation. These two programs generated the ownship and target aircraft flight dynamics. The direct pilot interaction with the cockpit was controlled by the VAPS software on the Onyx 2 workstation. Since the toolset being used for this simulation did not include existing HLA components, these were added manually.

The earlier design and test work carried out by VPI on the D-SAFIRE components combined with the DMSO HLA RTI 1.3NG tools provided all of the necessary programming interfaces for integration with the HLA. The routines from the test stub program in **Figure 5** were used as the RTI communications calls. Accessing the required parameters required additional effort.

The methodology for acquiring all of the data fields required for the radar model, and for supplying those values to the ACD simulation relied upon specially coded Simulation to RTI

Interface Modules (SRIMs). CMC programmed the HLA interface to access the SRIMs for each of FLSIM, STAGE, and the VAPS cockpit displays and controls.. The overall design of the ACD can be seen in **Figure 7**.

The ACD SRIM ran on the same machine as STAGE and FLSIM. Communication between the HLA module and STAGE and FLSIM was done using shared memory to access the target and ownship data respectively. The radar properties were taken from the cockpit display simulation on the Onyx 2 workstation. A UDP connection was established by the SRIM between Onyx 1 and Onyx 2 in order to get the current radar parameters and forward them to SAFIRE using HLA communication mechanisms. The UDP connection was also used to deliver the radar status reports received from SAFIRE to the SRIM process running on Onyx 2. The radar detections received in the status reports were transferred to the cockpit display simulation.

Since some of the displays were attempting to present merged radar and other sensor information, not all of the information about the radar detections requested by the CMC programmers could be supplied by D-SAFIRE. The ACD SRIM took the necessary information from STAGE and used that to display the detection. In addition, some information required by D-SAFIRE was not generated by STAGE. The missing information was the line of sight velocity and acceleration for the target. These values were calculated by the ACD SRIM based on other information taken from STAGE.

For the execution of the federation, the RTIexecutive and fedex processes also ran on the Onyx 1 machine. These processes could have been run on any computer in the network but were run on the Onyx 1 workstation to reduce network communication requirements.

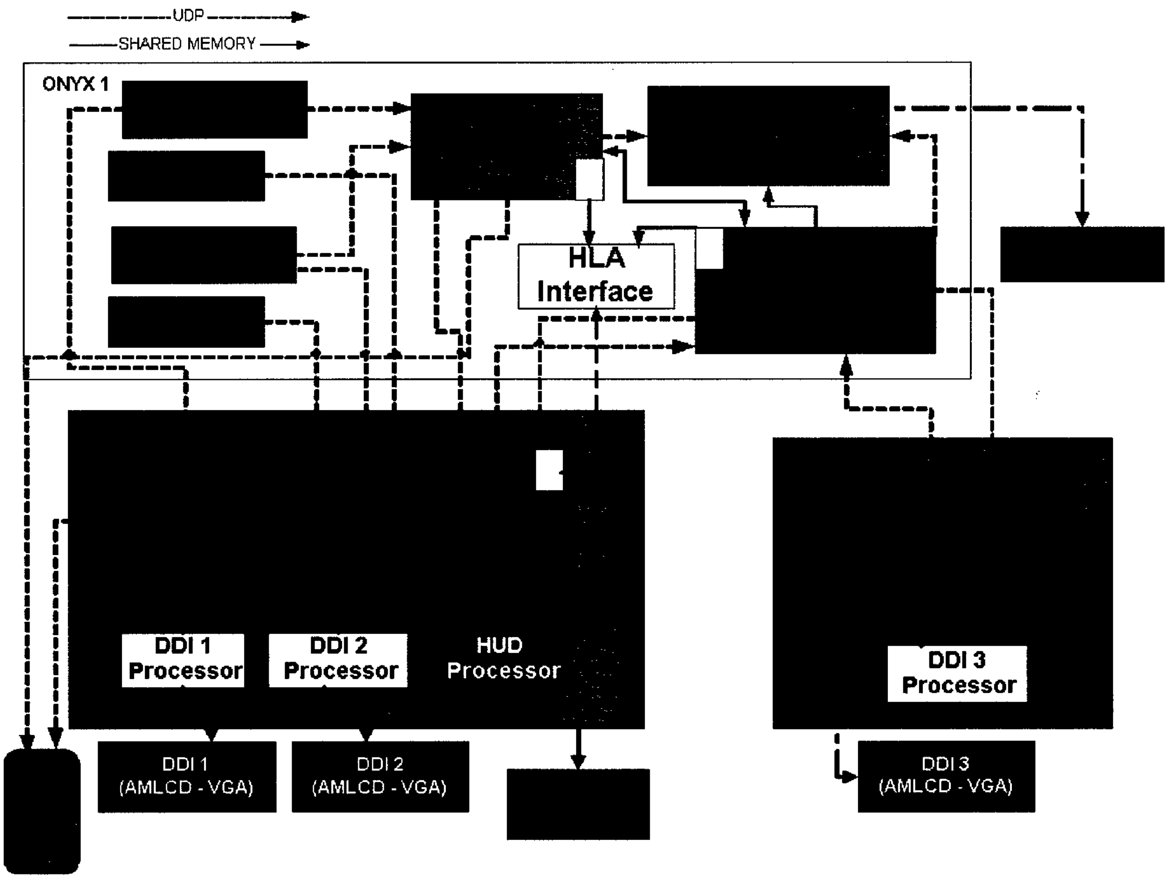

Figure 7: Air Crewstation Demonstrator software and hardware architecture

3. Summary of Implementation and Utilization

This section summarizes some of the difficulties in integrating the ACD and D-SAFIRE as well as how the simulation was operated. The first section discusses some of the problems encountered and solutions to those problems. The second section illustrates how the distributed simulation was started, run and shut down.

3.1 Capabilities and Limitations

In this section some of the difficulties that occurred during integration of the ACD with D-SAFIRE are discussed. Some modifications of the FOM occurred late in the integration phase of the project. These modifications are discussed later in this section. It was not possible to achieve the desired update rate for the simulation. This section begins with a discussion of the difficulty achieving the desired update rate.

An update rate of 30 Hz for the scenario state was set as a goal for the simulation. During integration of D-SAFIRE with the ACD, a rate of approximately 3Hz was all that could be achieved. A faster update rate caused the scenario information to be delivered to D-SAFIRE in bursts. This problem with the delivery of the simulation updates was never satisfactorily resolved.

One attempt to resolve the update rate problem consisted of the use of "best-effort" (UDP) connections instead of "reliable" (TCP) connections. It was thought that since the UDP connection requires less processing it might be possible to achieve a higher update rate. The type of connection used is specified in the federation execution details file "D-SAFIRE.fed". The "best-effort" connection resulted in a complete loss of communication between D-SAFIRE and the ACD. The reason for this complete loss was unknown.

In a second attempt to resolve the update problem, some of the communication parameters in the "RTI.rid" file were optimized. It was also hoped to optimize the data transfer times while trying to resolve the update rate problem. The parameters of interest specified the maximum size and wait time before sending data. The maximum time before sending data was set at 0.03s and the maximum number of bytes before sending was set at 256bytes. No optimisation of these parameters resolved the update rate problem. The final "RTI.rid" file contents can be seen in Annex C.

The bandwidth used on the ISDN line at the 2Hz update rate was approximately 60% of the 128Kbps capacity. This greatly exceeds the expected bandwidth required based on the amount of data being sent. This, combined with the lack of communication with UDP connection, indicates that either a large number of packets were being lost or corrupted between the CMC and DREO sites or there was other, unexpected traffic between the two sites.

In order to compensate for the poor update rate, extrapolation methods were added to D-SAFIRE. These methods update the aircraft and target flight dynamics based on the last received update. The extrapolation was applied after each Coherent Processing Interval (CPI) in D-SAFIRE. A CPI in D-SAFIRE simulates one processing cycle of the radar and takes between 6-8ms. The modular design of the SAFIRE model permitted the extrapolation code to be added with little impact on the existing code. Since the simulation did not include detailed tracking modes, such as STT, there were no requirements to smooth the parameter estimates between CPIs. If STT modes were to be used in this manner, further adaptation would be required to ensure that tracking filters performed correctly.

In the original specification for the simulation, D-SAFIRE was to simulate only the Range-While-Scan (RWS) mode of the APG-65. The Track-While-Scan (TWS) mode was added during implementation. The addition of the TWS mode required some modifications to the Radar Status Report in the FOM. The TWS mode required an additional field describing the track quality in the status report and a redefinition of the types of status reports possible. TWS mode was successfully added to the capability of D-SAFIRE with some limitations. CMC requested that the target aspect be supplied for all targets. D-SAFIRE was programmed based on older radar specifications and could generate the target aspect only for the Launch and Steer (L&S) target while in TWS mode. Thus it was not possible to send this information for all detections. As a work around for this problem CMC took the target aspect from STAGE. However, in order to extract the information from STAGE it was necessary to know which source target generated the detection. Since the radar simulation does not apply any target association between the information used to generate the target and the data used to generate the detections, this information is not available from the radar model. In order to ensure an exact match between the detection and the target it was decided to limit the number of targets sent to the radar model to one.

The use of only one target also solved an additional problem caused by the slow update rate. The target updates did not occur at a sufficient rate to permit constant updating of the radar display. Thus, the scenarios were set up so that all radar target information was extracted from the SRIMs. During the simulation the current flight data for the targets and the ACD were taken from the FLSIM and STAGE and sent to D-SAFIRE. D-SAFIRE would receive the current target, aircraft and radar control information from the ACD. The radar return was calculated from this information and the radar model then simulated the behaviour of the APG-65 radar. If a target was detected D-SAFIRE would generate a Radar Status Report and send it back to the ACD. When D-SAFIRE first detected the target a flag was set to activate the 'SAFIRE' target. The flag allowed the target data to be taken from STAGE and used to update the target information on the radar display. A timer was used to remove the target from the display if no update was received from D-SAFIRE within 8 seconds.

There were many user interface and display issues that could not be addressed in the limited time permitted for implementation of the prototype cockpit displays. The ACD implementation did not include the ability for the pilot to modify the radar antenna elevation, nor did it display the correct antenna elevation. Target aging was another function that was not implemented as defined for the CF-18. The ACD was designed to demonstrate the capabilities of the upgraded radar, but the radar model was based on the existing radar. Thus certain functionalities, such as the fusion of data link targets and radar targets were not implemented in the radar model, nor were they implemented in the ACD in a manner similar to the actual system.

3.2 Experiment Utilization

Once D-SAFIRE and the ACD were integrated the distributed simulation ran smoothly. The simulation protocol required that the 'SAFIRE' target be defined before the simulation was run. The initialization of HLA communications components was highly order dependent, and the simulation programs were required to started in a specific order. No human intervention, except by the ownship pilot, was required to keep the distributed simulation operating for a given scenario. At the end of the experiments, all of the processes were terminated manually.

As mentioned in the previous section, one target in the simulation was selected beforehand to be used in the distributed simulation. During typical operation, the chosen target's flight dynamics, along with Electromagnetic (EM) characteristics and Electronic Counter Measures (EMC) configuration for that target, were sent to D-SAFIRE. The flight dynamics (i.e. position, velocity and acceleration) and "Weapons Configuration" of the ACD were also sent to D-SAFIRE. In addition to the flight dynamic of the ACD and chosen target aircraft, the parameters controlling the radar, such as radar mode, azimuth and elevation centre and azimuth scan range were sent to D-SAFIRE. All display changes, and valid mode requests were detected by the D-SAFIRE radar model and reflected in the radar status reports. Due to the low update rate, and the requirement to simulate only one target, is was possible to run D-SAFIRE with the GUI active. Thus, while the radar model operators were unable to view the actual simulation in the ACD, they were able to observe the ownship and target aircraft manoeuvres via the local radar display.

Initial set up of the distributed simulation required FLSIM and STAGE programs to be started first. The RTIexecutive program was then started on the Onyx 1 workstation. The parent D-SAFIRE was then started and contacted the RTIexecutive running at the CMC facility to create join the simulation federation. The HLA integration module for the ACD was then started. The HLA integration module requested the creation of a radar object and immediately begin sending updates to D-SAFIRE. The updates would each contain the same data until the actual simulation began.

The ACD was demonstrated using the D-SAFIRE radar model in 26 of the 32 mission simulations. During each of these, the radar model generated the detections for the designated 'SAFIRE' target consistently. The limitations of working with the incomplete sensor model and interfaces were avoided through the careful design of the scenarios by the CMC experimenters. Occasionally targets were missed due to improper antenna elevation settings or the radar displays presented overly accurate data due to their reliance on the information from the STAGE program rather than on the radar outputs. This was especially true for the aspect vector information which was noted to be extremely stable in the ACD simulation.

4. Conclusions and Recommendations

Overall, the distributed simulation succeeded in providing a means of demonstrating radar performance issues by integrating a validated radar model with the cockpit simulation. Given the limited scope of the original tasking and the current limitations of processing and communications hardware, the system performed well, with many positive comments from the operators. The following sections summarize some of the lessons learned during the implementation of the distributed simulation and present some recommendations for future work.

4.1 Lessons Learned

One of the first lessons learned was differences between the human factors and sensor model simulation communities. The emphasis of the HFE simulation community, those implementing the ACD, was on the details in user interface. The performance of the sensor models in terms of 'correctness' were less important and they would be satisfied with results that looked correct. The sensor model simulation group at DREO was more concerned about simulating some of the limitations of the sensor to provide more realistic sensor performance. This had a larger impact on this simulation due to the different time lines between the two groups. The radar model and initial FOM were designed by the sensor model group with input from the ACD implementation team. However, the implementation of the radar model specific portions of the ACD were carried out late in the project and it was at this time that the impact of the different viewpoints became apparent.

One of the primary goals of the sensor model team was to determine the effort required to convert the stand alone legacy radar simulation into a part of a larger distributed simulation. Despite a lack of previous experience with HLA by almost all of the participants, the infrastructure provided by the HLA was readily adapted to the existing simulations. The original design of the SAFIRE radar model was very modular, and the separation between the GUI and the SSS permitted the insertion of the HLA components relatively easily. The implementation of the distributed radar simulation demonstrated that the sensor models, if designed in a modular fashion, are readily adapted to a distributed simulation environment. Detailed knowledge of HLA is most important at the beginning of the project in determining optimal design decisions and at the end of the project in achieving the best performance of the simulation.

Communications expertise for the communication protocol being used is also important when attempting to achieve realtime performance. One of the problems with the simulation was the low update rate of only 2Hz. This was caused by the poor network performance over the ISDN backbone, data being sent in uneven bursts, possible excessive network traffic, and the complete loss of the UDP packets when attempting to use the 'best-effort' mode of the HLA federation. While HLA removes the necessity of all of the programmers from understanding the underlying communications protocols, it is necessary to have someone involved who understands the effects of the various choices. Later testing[8] indicated that with a single target, and the GUI disabled, D-SAFIRE is capable of maintaining a an update rate of 20Hz over a standard 10Base T Ethernet connection. For 4 targets this drops to 8Hz, but still exceeds the 2Hz used in the distributed simulation.

4.2 Recommendations

The results of this simulation effort have demonstrated that modular sensor models can be integrated into distributed simulations with little modification of the current code. However, realtime performance issues currently limit the use of detailed models such as SAFIRE in a human-in-the-loop simulation. These models often have to run in limited scenarios, with certain capabilities removed. Thus for these types of simulations, it is recommended that simpler representative models be used. An example of this for the CF-18 is the radar model currently in use with the CF-18 ACES project [9].

One area where this distributed simulation capability would be very useful with detailed simulations are complete system simulations. In addition to the SAFIRE radar model, there currently exists several sensor model simulations for the CF-18 aircraft such as electronic support measure (ESM) sensors. Combining these with a flight simulator and scenario management tool would enable the entire aircraft sensor environment to be simulated in a co-ordinated fashion. This first stage would permit one aircraft using ESM sensors to detect the radar of the a second aircraft, which would in turn, send a selected jamming mode back to the SAFIRE radar model. This would allow the verification of various jamming programs against multi-mode radars as opposed to verifying only specific techniques against a single mode. The integration of missile flight and missile seeker models would also permit the verification of jamming programs on missile effectiveness in more realistic circumstances than are currently possible. These types of simulation do not require realtime performance. It is highly recommended that future simulations proceed along these lines to provide significantly improved system performance estimates for future sensor systems.

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Annex A Network Configuration for SAFIRE HLA

The following is a description of the configuration parameters used for the ACD HLA ISDN network connections. Note that arbitrary addresses are used since the connection is assumed to be point to point over the switches and that any address will not cause the system to generate requests outside of the dedicated connection configured in this way.

DREO ISDN Router Configuration

Switch type	NI-1
Channel Usage	Switch/Switch
Contact number	as provided by telecommunications provider
SPID numbers	as provided by telecommunications provider
Local name	dreo
Local router IP address	131.136.36.1/24
Remote name	baesystems
Remote router IP address	192.75.86.170/24
Remote dial-up number	as provided by telecommunications provider
Route	IP
Send auth/Recv auth	PAP

Network IP Addresses for Federation

DREO observer (dreo_nt/dreo_hla_node)	131.136.36.71
DREO Radar Model / Schroeder	131.136.36.74
BAE RTI	192.71.86.160

Configuration of DREO Sun Workstation (SAFIRE platform)

1) Modify /etc/nsswitch.config
    a. This file is modified to ensure that files are check before [NOT FOUND = return]. Otherwise, /etc/hosts and /etc/passwd are not checked.
2) /etc/hosts: add above ip names and addresses
3) /etc/passwd: Copy hla users to passwd file. Copy passwords to /etc/shadow.
4) /etc/vfstab: Ensure no remote file systems are mounted on Schroeder. Also unmount all volumes from other locations. I.e. unmount /fluorine on Linus.
5) /etc/auto_home: For users who may log on to Schroeder, ensure that their accounts are created locally (added /fluorine/home).
6) /etc/defaultdomain: A copy of this file is stored in defaultdomain.dreo. This must be deleted to boot on the restricted ISDN network, and copied back from defaultdomain.dreo to reboot on the DREO LAN.

Annex B D-SAFIRE Federation Execution Details

```
(FED
(Federation CF-18_APG-65_simulation)
(FEDversion v1.3)
 (spaces
 )
 (objects
   (class ObjectRoot
     (attribute privilegeToDelete  reliable timestamp)
     (class RTIprivate)
 (class Aircraft
    (attribute TSPI best_effort receive)
    (attribute Weapon_Configuration best_effort receive)
 )
 (class Radar
    (attribute Radar_Parameters best_effort receive)
    (attribute Radar_Status best_effort receive)
    (attribute Target_Processing_List best_effort receive)
 )
 (class Manager
 (class Federation
    (attribute FederationName reliable receive)
    (attribute FederatesInFederation reliable receive)
    (attribute RTIversion reliable receive)
    (attribute FEDid reliable receive)
    (attribute LastSaveName reliable receive)
    (attribute LastSaveTime reliable receive)
    (attribute NextSaveName reliable receive)
    (attribute NextSaveTime reliable receive)
 )
 (class Federate
    (attribute FederateHandle reliable receive)
    (attribute FederateType reliable receive)
    (attribute FederateHost reliable receive)
    (attribute RTIversion reliable receive)
    (attribute FEDid reliable receive)
    (attribute TimeConstrained reliable receive)
    (attribute TimeRegulating reliable receive)
    (attribute AsynchronousDelivery reliable receive)
    (attribute FederateState reliable receive)
    (attribute TimeManagerState reliable receive)
    (attribute FederateTime reliable receive)
    (attribute Lookahead reliable receive)
    (attribute LBTS reliable receive)
    (attribute MinNextEventTime reliable receive)
    (attribute ROlength reliable receive)
    (attribute TSOlength reliable receive)
    (attribute ReflectionsReceived reliable receive)
    (attribute UpdatesSent reliable receive)
```

```
    (attribute InteractionsReceived reliable receive)
    (attribute InteractionsSent reliable receive)
    (attribute ObjectsOwned reliable receive)
    (attribute ObjectsUpdated reliable receive)
    (attribute ObjectsReflected reliable receive)
  )
  )
    )
 )
 (interactions
   (class InteractionRoot reliable timestamp
     (class RTIprivate  reliable timestamp)
  (class Terminate_Simulation reliable receive
    (parameter SAFIRE_terminate)
  )

  (class Create_Radar_Object reliable receive
    (parameter SAFIRE_execute)
  )

  (class Destroy_Radar_Object reliable receive
    (parameter SAFIRE_exit)
  )

  (class Radar_Pause_Request reliable receive
    (parameter SAFIRE_pause)
  )

  (class Radar_Continue_Request reliable receive
    (parameter SAFIRE_continue)
  )

  (class Update_Aircraft best_effort receive
    (parameter Aircraft)
  )

  (class Update_Target_Processing_List best_effort receive
    (parameter trg_prl)
  )

  (class Radar_Parameters best_effort receive
    (parameter rdr_prm)
  )

  (class Radar_Status_Report best_effort receive
    (parameter rdr_sts)
  )

  (class Manager reliable receive
  (class Federate reliable receive
    (parameter Federate)
```

```
(class Request reliable receive
(class RequestPublications reliable receive
)

(class RequestSubscriptions reliable receive
)

(class RequestObjectsOwned reliable receive
)

(class RequestObjectsUpdated reliable receive
)

(class RequestObjectsReflected reliable receive
)

(class RequestUpdatesSent reliable receive
)

(class RequestInteractionsSent reliable receive
)

(class RequestReflectionsReceived reliable receive
)

(class RequestInteractionsReceived reliable receive
)

(class RequestObjectInformation reliable receive
  (parameter ObjectInstance)
)

)

(class Report reliable receive
(class ReportObjectPublication reliable receive
  (parameter NumberOfClasses)
  (parameter ObjectClass)
  (parameter AttributeList)
)

(class ReportObjectSubscription reliable receive
  (parameter NumberOfClasses)
  (parameter ObjectClass)
  (parameter Active)
  (parameter AttributeList)
)

(class ReportInteractionPublication reliable receive
  (parameter InteractionClassList)
)
```

```
(class ReportInteractionSubscription reliable receive
  (parameter InteractionClassList)
)

(class ReportObjectsOwned reliable receive
  (parameter ObjectCounts)
)

(class ReportObjectsUpdated reliable receive
  (parameter ObjectCounts)
)

(class ReportObjectsReflected reliable receive
  (parameter ObjectCounts)
)

(class ReportUpdatesSent reliable receive
  (parameter TransportationType)
   (parameter UpdateCounts)
)

(class ReportReflectionsReceived reliable receive
  (parameter TransportationType)
   (parameter ReflectCounts)
)

(class ReportInteractionsSent reliable receive
  (parameter TransportationType)
   (parameter InteractionCounts)
)

(class ReportInteractionsReceived reliable receive
  (parameter TransportationType)
   (parameter InteractionCounts)
)

(class ReportObjectInformation reliable receive
  (parameter ObjectInstance)
   (parameter OwnedAttributeList)
   (parameter RegisteredClass)
   (parameter KnownClass)
)

(class Alert reliable receive
  (parameter AlertSeverity)
   (parameter AlertDescription)
   (parameter AlertID)
)

(class ReportServiceInvocation reliable receive
  (parameter Service)
```

```
    (parameter Initiator)
    (parameter SuccessIndicator)
    (parameter SuppliedArgument1)
    (parameter SuppliedArgument2)
    (parameter SuppliedArgument3)
    (parameter SuppliedArgument4)
    (parameter SuppliedArgument5)
    (parameter ReturnedArgument)
    (parameter ExceptionDescription)
    (parameter ExceptionID)
  )

)

(class Adjust reliable receive
(class SetTiming reliable receive
  (parameter ReportPeriod)
)

(class ModifyAttributeState reliable receive
  (parameter ObjectInstance)
   (parameter Attribute)
   (parameter AttributeState)
)

(class SetServiceReporting reliable receive
  (parameter ReportingState)
)

(class SetExceptionLogging reliable receive
  (parameter LoggingState)
)

)

(class Service reliable receive
(class ResignFederationExecution reliable receive
  (parameter ResignAction)
)

(class SynchronizationPointAchieved reliable receive
  (parameter Label)
)

(class FederateSaveBegun reliable receive
)

(class FederateSaveComplete reliable receive
  (parameter SuccessIndicator)
)
```

```
(class FederateRestoreComplete reliable receive
  (parameter SuccessIndicator)
)

(class PublishObjectClass reliable receive
  (parameter ObjectClass)
   (parameter AttributeList)
)

(class UnpublishObjectClass reliable receive
  (parameter ObjectClass)
)

(class PublishInteractionClass reliable receive
  (parameter InteractionClass)
)

(class UnpublishInteractionClass reliable receive
  (parameter InteractionClass)
)

(class SubscribeObjectClassAttributes reliable receive
  (parameter ObjectClass)
   (parameter AttributeList)
   (parameter Active)
)

(class UnsubscribeObjectClass reliable receive
  (parameter ObjectClass)
)

(class SubscribeInteractionClass reliable receive
  (parameter InteractionClass)
   (parameter Active)
)

(class UnsubscribeInteractionClass reliable receive
  (parameter InteractionClass)
)

(class DeleteObjectInstance reliable receive
  (parameter ObjectInstance)
   (parameter Tag)
   (parameter FederationTime)
)

(class LocalDeleteObjectInstance reliable receive
  (parameter ObjectInstance)
)

(class ChangeAttributeTransportationType reliable receive
```

```
  (parameter ObjectInstance)
  (parameter AttributeList)
  (parameter TransportationType)
)

(class ChangeAttributeOrderType reliable receive
  (parameter ObjectInstance)
  (parameter AttributeList)
  (parameter OrderingType)
)

(class ChangeInteractionTransportationType reliable receive
  (parameter InteractionClass)
  (parameter TransportationType)
)

(class ChangeInteractionOrderType reliable receive
  (parameter InteractionClass)
  (parameter OrderingType)
)

(class UnconditionalAttributeOwnershipDivestiture reliable receive
  (parameter ObjectInstance)
  (parameter AttributeList)
)

(class EnableTimeRegulation reliable receive
  (parameter FederationTime)
  (parameter Lookahead)
)

(class DisableTimeRegulation reliable receive
)

(class EnableTimeConstrained reliable receive
)

(class DisableTimeConstrained reliable receive
)

(class EnableAsynchronousDelivery reliable receive
)

(class DisableAsynchronousDelivery reliable receive
)

(class ModifyLookahead reliable receive
  (parameter Lookahead)
)

(class TimeAdvanceRequest reliable receive
```

```
    (parameter FederationTime)
  )

  (class TimeAdvanceRequestAvailable reliable receive
    (parameter FederationTime)
  )

  (class NextEventRequest reliable receive
    (parameter FederationTime)
  )

  (class NextEventRequestAvailable reliable receive
    (parameter FederationTime)
  )

  (class FlushQueueRequest reliable receive
    (parameter FederationTime)
  )

 )

 )

 )

   )
 )
)
```

Annex C RTI.rid file

```
(RTI
 (ProcessSection
  (RtiExecutive
   (RtiExecutiveEndpoint 192.75.86.53:20065)
   ;;(RtiExecutiveEndpoint 131.136.36.71:20065)


   ;; remember that rtiexec -multicastDiscoveryEndpoint flag must
   ;; match this, or you'll get NameService errors
   ;;(RtiExecutiveMulticastDiscoveryEndpoint 224.9.9.2:12345)
   ;;(NumberOfAttemptsToFindRtiExecutive 10)
   )
  )
 )

 (FederationSection
  ;;(FederationExecutive
   ;;(FilenameToRedirectStdout "log.txt")
   ;;(FilenameToRedirectStderr "log.txt")
  ;;)
  (Networking
   (BundlingOptions
    (UDP
     (MaxTimeBeforeSendInSeconds 0.0001)
     (MaxBytesBeforeSend    256)
    )
    (TCP
     (MaxTimeBeforeSendInSeconds 0.03)
     (MaxBytesBeforeSend    256)
    )
   )
   (MulticastOptions
    ;; having different federations on network use different ranges of
    ;; multicast addresses will help performance
    (BaseAddress 224.100.0.0)
    ;;(MaxAddress 239.255.255.255)
   )
  )

  (Advisories
   ;;(RelevanceAdvisoryAttributeInstanceHeartbeatInSeconds Off)
   ;;(RelevanceAdvisoryAttributeInstanceTimeoutInSeconds Off)
   ;;(RelevanceAdvisoryInteractionClassHeartbeatInSeconds Off)
   ;;(RelevanceAdvisoryInteractionClassTimeoutInSeconds Off)
   ;;(RelevanceAdvisoryObjectClassHeartbeatInSeconds Off)
   ;;(RelevanceAdvisoryObjectClassTimeoutInSeconds Off)
  )
```

```
 (FederateSection
  (EventRetractionHandleCacheOptions
   ;; the next two options will disable event retractions, which is
   ;; OK since helloworld doesn't use them
   (MinimumCacheSizeBeforePerformingPurge 0)
   (NumberOfEventRetractionHandlesToCreateBeforeStartingNewPurgeCycle 0)
  )
 )
)
)
```

List of Symbols, Abbreviations, Acronyms and Initialisms

ACD	Air Crewstation Demonstrator
CMC	Canadian Marconi Company
D-SAFIRE	Distributed-SAFIRE
DDI	Digital Display Indicator
DMSO	Defence Modelling and Simulation Office
DREO	Defence Research Establishment Ottawa
ECCM	Electronic Counter Counter Measure
ECM	Electronic Counter Measure
EM	ElectroMagnetic
ESM	Electronic Support Measure
FLSIM	Flight Simulator
FOM	Federation Object Model
HFE	Human Factors Engineering
HLA	High Level Architecture
HUD	Head Up Display
IEEE	Institute of Electrical and Electronics Engineers
ISDN	Integrated Services Digital Network
L&S	Launch and Steer
LAN	Local Area Network
OMDT	Object Model Development Tool
RTI	Run-Time Infrastructure
RWS	Range While Scan
SAFIRE	Simulator for Advanced Fighter Radar ECCM Development
SRIM	Simulation to RTI Interface Module
SSS	Scientific Simulation Software

STAGE	Scenario Toolkit And Generation Environment
STT	Single Target Track
TCP	Transport Control Protocol
TSPI	Time Space Position Indication
TWS	Track While Scan
UDP	User Datagram Protocol

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Defence Research and Development Canada (DRDC) has been developing a low cost means to evaluate the integration of new display equipment for the Air Force. The result has been the Aircraft Crewstation Demonstrator (ACD), which is capable of simulating the cockpit of an aircraft for human factors evaluation (HFE). In order to support future display upgrades within the cockpit of the CF-188, DRDC contracted an HFE study of the CF-188 displays, especially the radar displays associated with radar and data link. Earlier work at the Defence Research Establishment Ottawa (DREO) had resulted in a high fidelity simulation of the air to air modes of a fighter radar. In order to develop as representative display as possible, a task to integrate the ACD with the DREO radar simulation as a distributed simulation was included with the HFE study. This report describes the use of the high level architecture (HLA) to combine these two disparate simulations into one distributed simulation. The results indicate that HLA is an effective means of combining different models to provide an improved simulation to the user. Advantages and limitations are discussed, as is a proposed future architecture.

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High Level Architecture (HLA)
CF-18
Radar Simulation
Distributed Simulation

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