A VIRTUAL ENVIRONMENT, DISTRIBUTED SIMULATION, UAV TESTBED

Jon Blacklock*, Lucien Zalcman.**
***The Australian Defence Department**
Defence Science and Technology Organisation
jon.blacklock@dsto.defence.gov.au,
****Zalcman Consulting**
lucien_b_zalcman@yahoo.com.au

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Abstract

The Australian Defence Force (ADF) has indicated an interest in purchasing the High Altitude, Long Endurance, Global Hawk Unmanned Air Vehicle (UAV). A Virtual Environment, Distributed Simulation, UAV Testbed proposal has been developed by the Australian Defence Department's Defence Science and Technology Organisation (DSTO). This proposal was developed using the lessons learned from the development by DSTO of the Air Defence Ground Environment Simulator (ADGESIM) now used by the Royal Australian Air Force (RAAF) to train Air Defence Controllers.

The UAV testbed is being developed as an Advanced Concept Technology Demonstrator and is designed to support UAV training, experimentation and capability development in a virtual environment.

This paper describes and discusses some of the innovations, technologies, components, and lessons learned so far in the development of the ADGESIM UAV testbed.

1 Introduction

In some cases the ADF has no option but to use live assets to support training. Reduced budgets have impacted on asset availability and the frequency and scale of joint and combined exercises. Reliance on live assets or the use of existing, ageing and outdated simulators is no longer viable and live training, enterprise level exercises are virtually non-existent. To address this problem the ADF is adopting Advanced Distributed Simulation technologies to enhance training capabilities, increase training opportunities and reduce costs.

2 The DSTO Advanced Distributed Simulation Laboratory

In 1998 the need for study into advanced distributed simulation technology to support training led to the establishment of the DSTO Advanced Distributed Simulation Laboratory (ADSL) at DSTO in Fishermans Bend, Melbourne funded by the RAAF's Virtual Air Environment project.

Most ADF simulation projects result in highly specialised, large software applications that are high risk, expensive to maintain, are usually delivered over time, over budget, and do not provide the specified functionality.

The ADSL promotes the use of modular Commercial-Of-The-Shelf (COTS), distributed simulation applications however it is unlikely that an operational simulator can be completely created from available COTS applications. To provide an appropriate interface *customised thin-client* applications have to be developed where no commercial equivalents exist. However because development focuses mainly on these small, thin-client applications a simulator can be delivered cheaply, quickly, and at lower risk when compared to the high risk, ADF simulation applications mentioned above.

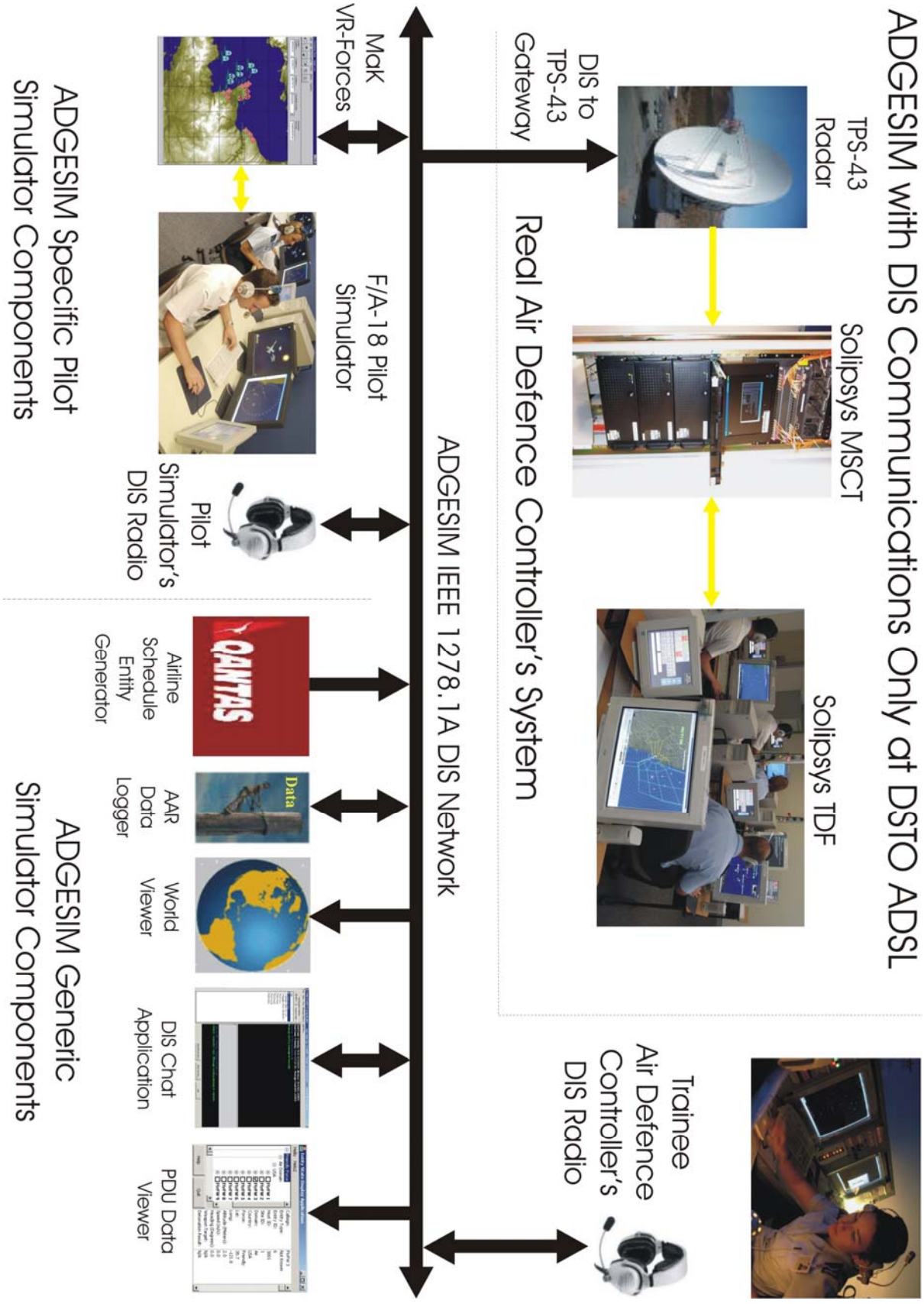

Fig. 1. Royal Australian Air Force Air Defence Ground Environment Simulator (ADGESIM).

3 The DSTO Developed Air Defence Ground Environment Simulator (ADGESIM)

The Air Defence Ground Environment Simulator (ADGESIM [1]) (Figure 1) has recently been developed using lessons learned from the DSTO ADSL. ADGESIM is comprised of eight, customized, thin-client applications interoperating with five COTS products.

Each ADGESIM application is a standalone, distributed simulation application that has no requirement of, or knowledge of, the presence of any other ADGESIM or distributed simulation application. ADGESIM applications can be reused in other distributed simulation, virtual environments.

The ADGESIM trainer has been successfully deployed and is used operationally to train Air Defence Controllers at various RAAF Air Bases.

From Figure 1 the ADGESIM architecture is comprised of three main sub-systems. These are:

- The real system - the Solipsys Multi-Source, Correlator, Tracker (MSCT) back-end and the Solipsys Tactical Display Framework (TDF) front-end. The use of this stimulated, real system component approach eliminates many trainer concurrency problems that traditionally occur in emulated systems;
- The ADGESIM specific components (the Westinghouse TPS-43 radar system replaced by) the DIS (Distributed Interactive Simulation) to TPS-43 Gateway and the Pilot Simulator component. These components are designed to provide the main simulation functionality required by the ADGESIM – the radar system, the wingman, the red force, etc. at the fidelity required; and
- The ADGESIM generic simulator components that can be reused by any simulator.

Many (if not all) real-time training simulation systems may be able to be constructed using this approach and the ADGESIM architecture can be viewed as a generic, real-time, training simulator architecture! Note also that this architecture is compatible with the Reuse, Composability, Peer-to-Peer, Test and Training Enabling Architecture (ie TENA [2)]) whereby reuse can occur at any scale – reusable components can be combined to create an application, a system, or a system-of-systems.

4 The ADGESIM Global Hawk, UAV Simulator

The Australian Defence Force has indicated an interest in purchasing the High Altitude, Long Endurance, Global Hawk UAV (Figure 2). Because of the high (downlink) bandwidth data communications requirements (up to hundreds of Mbps) of a Global Hawk UAV, that would normally be provided by a military or commercial satellite, it will be expensive to carry out beyond line-of-site training exercises. Therefore beyond line-of-site training exercise time using the real UAV will be limited and the need to conduct most training exercises will most likely be met by using simulators where high fidelity, virtual environment, simulator training would be indistinguishable from real (training) events.

Fig. 2. A Global Hawk UAV.

A Virtual Environment, Distributed Simulation, UAV Testbed proposal, based on the lessons learned from the development of the ADGESIM, has been developed by DSTO. The ADGESIM Global Hawk UAV test bed will be developed as an Advanced Concept Technology Demonstrator and is designed to support high fidelity UAV training, experimentation and

capability development in a virtual environment. Example applications for such a UAV testbed are Human Machine Interface development, autonomous operations research, distributed simulation development etc. The proposed UAV testbed simulator is shown in Figure 3.

4.1 ADGESIM Reusable Components

The ADGESIM generic components to be reused in the ADGESIM UAV simulator are described in detail below.

4.1.1 The ADGESIM Airline Scheduler

The ADGESIM Airline Scheduler populates the synthetic environment with simple, scripted entities (e.g. airline schedules) and controls behaviours such as entity takeoff/start, navigation, height changes etc.

Air route, waypoint, airfield, aircraft attributes, DIS enumerations, and flight schedule data are available to the ADGESIM Airline Scheduler. The entire flight schedule for QANTAS will be added, and over time, schedule libraries will be created for other world airlines and various "interesting" surveillance scenarios.

The Scheduler is being updated to manage surface and space traffic to accommodate wide area surveillance training where simulated space and Over-The-Horizon-Radar sensors are required.

4.1.2 The ADGESIM Data Logger

In practice COTS Data Loggers do not always provide the full functionality required in real military training exercises. The ADGESIM DIS Data Logger [3] has been developed to address some of these issues.

It can record and filter DIS Protocol Data Unit (PDU) data over multiple ports to aid Wide Area Network management. Simple DIS exercise metrics, that are useful in the setup stages of a DIS exercise to spot obvious incompatibility and interoperability problems, can be viewed. Data can be replayed in the forward or reverse direction at various speeds starting at any time within the data file.

The ADGESIM DIS Data Logger has been designed to be the starting component of a more capable After Action Review (AAR) or DIS Interface Compliance Testing application.

Data already recorded can be extracted whilst data is still being logged allowing testing, analysis and logging to occur concurrently. This is useful when:

- Access to simulation (i.e. real platform) equipment is limited; and
- Data can be analysed whilst a training exercise is still in progress therefore reducing the time required before the AAR process can start at the completion of the exercise.

4.1.3 The ADGESIM World Viewer

The ADGESIM World Viewer application is a DIS, 2D/3D viewer based on a high resolution, texture of the world. The World Viewer provides a symbolic representation of any DIS entity participating in an exercise along with airports, waypoints, routes and overlays on an orthographic projection of the world.

User defined text datablocks (callsign, entity type, heading, speed, IFF (Identify Friend or Foe), lat/long etc.) can be displayed for each entity permanently or only when the mouse is positioned over the DIS entity symbol. Other display options such as radar cones, sensor volumes, entity snap-to-ground, ground-altitude entity poles, entity history dots, multiple symbology sets including the MIL-STD-2525B symbology set, etc. are also supported.

The user can zoom in or out and rotate the world with the center of the world always located at the center of the screen. A pan mode is also available. The user's viewpoint may be fixed in space or locked on to any particular entity. A moving map capability is available.

A World Viewer, common code, library has been developed. This common library is used by other ADGESIM applications.

4.1.4 The ADGESIM Chat Application

The ADGESIM Chat application [4] is used for chatting, via text messages, between exercise participants over a distributed simulation, exercise network.

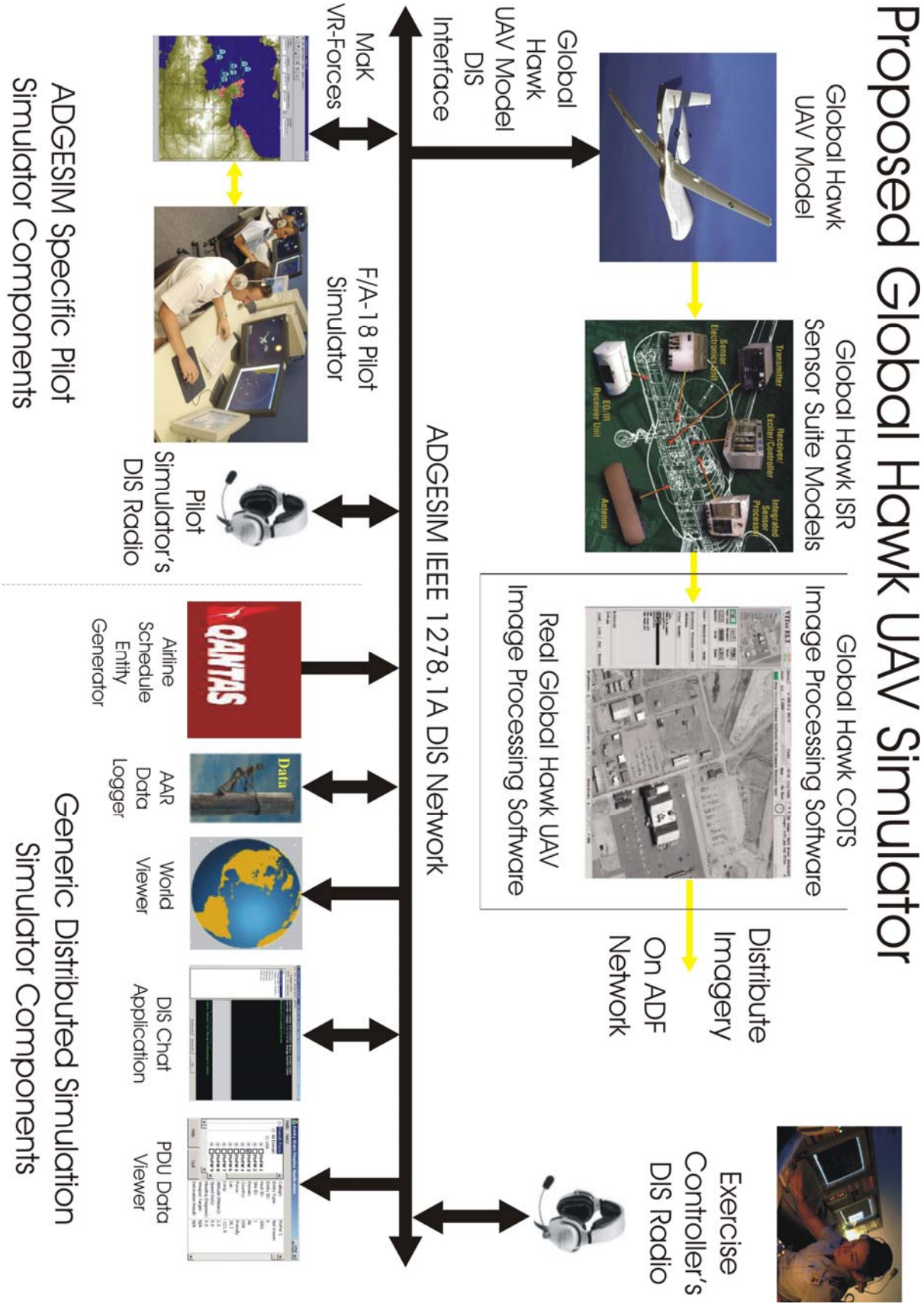

Fig. 3. The ADGESIM Global Hawk UAV Testbed.

The ADGESIM Chat application is a stand-alone, peer-to-peer application and does not require any external server application. Most other Chat programs are client-server applications that require access to an external server on the internet. This is not desirable on a classified network.

The peer-to-peer, ADGESIM Chat application installs easily and once initialised broadcasts its presence to other ADGESIM Chat applications to enable them to automatically configure their required chat group as specified in each application's startup configuration file.

The DIS Chat traffic (ie DIS Comment PDUs) can be recorded and synchronously replayed, along with the other exercise DIS PDUs, at AAR time using any COTS DIS data logger.

The ADGESIM DIS Chat application can operate in one of three modes:

- Instructor mode – can participate in an exercise and view all chat application messages that are sent over the network on the chosen port;
- Participant mode – the normal operating mode that interacts with messages and users belonging to user chosen groups; and the
- After Action Review mode - monitors or imitates a user that is currently participating, or has previously participated, in an exercise.

The AAR mode is not normally available in COTS applications. This mode is designed to help in the AAR process and has been demonstrated in the Chat application with the objective that it will eventually be included in other ADGESIM applications.

4.1.5 The ADGESIM PDU Data Viewer

The ADGESIM PDU Data Viewer application displays (user defined) data describing selected entity (platforms and weapons) activity within the virtual battle-space environment. The user interface comprises a dynamic tree-structured list of entities and a dynamically sized area for viewing the chosen entity information.

Data from entities detected in the virtual battle-space can be processed into a tree-structured entity list according to its identity and a user defined structure such as categories of Force, Domain, and Country. Each entity can be listed by call sign and child branches that contain entity information including Entity Type, Enumeration, Entity ID, Site ID, Host ID, Force, Domain, Country and Category. Alternatively no category can be specified where the tree structure would disappear altogether and a list of entities would appear in alphabetic order sorted according to call sign.

What entity information is displayed (a minimum of PDU type, call-sign and Entity Type) is determined at startup from a configuration file but can also be dynamically modified. If a chosen entity fires a weapon or is targeted by a weapon additional Fire/Detonation information is displayed.

The PDU Data Viewer is designed to focus the observer's attention on relevant information from important entities in an exercise.

4.1.6 The ADGESIM DIS Radio System

The ADGESIM DIS Radio/Intercom Communications system (DISVOX) is used for demonstration purposes in the ADSL and is not used operationally. A COTS, DIS/HLA (High Level Architecture), radio and intercom software toolkit [5] is used to produce and process DIS Transmitter and Signal PDUs.

Although DIS version 1278.1A [6] does have an Intercom PDU this functionality is implemented in DISVOX by assigning radio channels with frequencies less than 1000Hz as intercoms for both DIS 1278.1 and 1278.1A systems. This is a de-facto standard method of implementing intercoms in DIS simulators.

The DISVOX GUI is "skinable" and these (bmp/xml configuration file) skins are designed to duplicate the "look and feel" of real radio/intercom systems. A single DISVOX application can support up to a maximum of 18 radios and 18 intercoms on the one skin.

DISVOX has been demonstrated in the ADSL to be interoperable with the General Dynamics ModIOS ToolSuite, ASTi and US

Navy Battle Fleet Tactical Trainer DIS radio/intercom systems.

4.2 ADGESIM Specific Simulator Components

The ADGESIM Pilot Interface application is considered as a simulator specific (ie essential) application in the ADGESIM. It has been specifically designed (in close consultation with RAAF Air Defence Controller trainers) to provide red and blue virtual fighter entities with the appropriate capabilities and fidelity as required for ADGESIM.

However for the ADGESIM UAV simulator the ADGESIM Pilot Interface application is considered as another reusable ADGESIM component that can provide red and blue virtual fighter entities. It is not an essential component of the ADGESIM UAV simulator.

A specific simulator component may be specific to a particular simulator however it may be considered as a reusable, not essential, generic component in another simulator.

4.2.1 The ADGESIM Pilot Interface Application

The Pilot Interface application allows pilot operators to create and fly simulated aircraft entities generated and controlled by a VR-Forces COTS back-end.

Entity position, performance and system information are controlled by the Pilot simulator to simulate real-world pilots and formations of aircraft. Each Pilot Interface can control up to twelve entities by calling VR-Forces server functions over the network. Several custom VR-Forces controllers were developed as part of the development of the Pilot Interface client application to achieve more realistic aircraft control. Multiple Pilot Interfaces can communicate with a single VR-Forces server or with several VR-Forces servers to make the ADGESIM Pilot Interface a highly scalable application.

Multiple Pilot Interfaces communicate with each other to provide electronic warfare indicators such as radar “spikes”, radar mode changes, and weapon launch indications. Pseudo tactical data link information will be incorporated to allow cooperative engagement of targets. The Pilot Interface supports IFF, weapons deployment, aircraft to be grouped into formations and provides automated manoeuvres such as heading snaps, postholes, navigate to a point, and follow or patrol a route that reduces operator workload.

The Pilot Interface application could be used in the ADGESIM UAV simulator to provide higher fidelity aircraft entities than those provided by the Airline Scheduler application to test UAV collision avoidance algorithms.

4.3 ADGESIM UAV Specific Simulator Components

In the ADGESIM Global Hawk UAV simulator there are two specific simulator components.

4.3.1 The Global Hawk UAV Flight Model

The Global Hawk is a highly autonomous UAV in that requires no human intervention once a mission has been programmed into the aircraft. It can take-off, proceed to the target area, carry out the mission, and return to base and land completely automatically. A mission plan can be modified once the UAV is under way.

Initially a simple Global Hawk aircraft flight model will suffice. In a typical mission profile, the Global Hawk will take off, climb to 50,000 feet within 200 nm, cruise to 65,000 feet and the mission area at operating range, loiter to collect the required data, fly back and land [7].

The Airline Scheduler application already has such a *no human intervention* flight model capability including the ability to modify the mission plan once the UAV is under way. However (minor) modification will be required to provide a specific UAV *loiter to collect data* functionality.

4.3.2 The Global Hawk UAV Sensor Suite Payload Model

The Global Hawk does not carry weapons. It normally carries an Intelligence, Surveillance, and Reconnaissance (ISR) category payload.

The Raytheon Integrated Sensor Suite (ISS) ISR payload (Figure 4) combines a cloud penetrating, synthetic aperture radar (SAR)

system, including a ground moving target indicator (GMTI), with a high resolution electro-optical (EO) digital camera and an infrared (IR) sensor. Imagery can be collected at up to 30 frames per second. These sensors are capable of operating in various modes including a point at target (continuous stare) mode.

The integrated design of the ISS enables the ISS to operate either the EO or the IR sensor simultaneously with the SAR/GMTI sensor therefore enabling commanders to see through adverse weather, day or night; detect targets moving at greater than 4 knots (7.5 km/h or 4.5 mph); and identify various types of vehicles, aircraft and missiles.

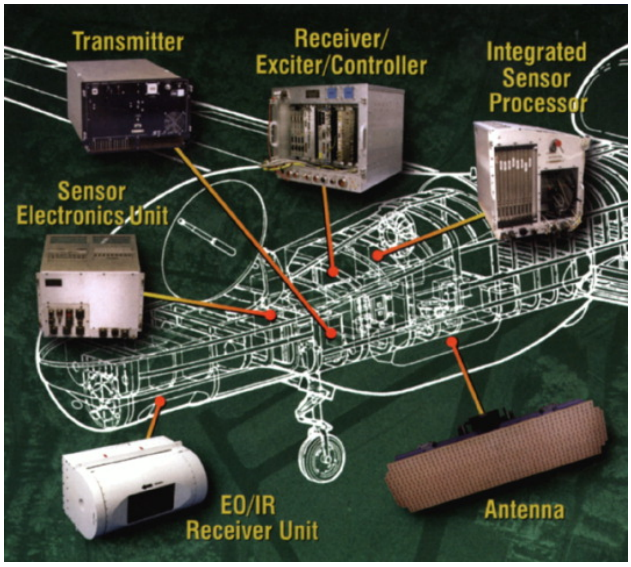

Fig. 4. Global Hawk ISR Sensor Suite Components.

The EO/IR and SAR data are preprocessed on the UAV and transmitted to ground stations in National Imagery Transmission Format Standard (NITFS) 2.0 format where the data can be processed further (ie exploitation) prior to dissemination. GMTI data is transmitted as text data providing location, range, and velocity.

Standard commercial and military communications can be used to disseminate near real-time information to geographically dispersed commanders.

The ADGESIM Global Hawk UAV simulator will, mainly using COTS software, output EO/IR, SAR and GMTI data in exactly the same format as does the real Global Hawk UAV.

The ADGESIM Global Hawk UAV entity, controlled by the ADGESIM Airline Scheduler application, will fly through an interoperable virtual environment, with an attached ADGESIM, Global Hawk, UAV Sensor Suite Payload model. The UAV Sensor Suite Payload model will interoperate with the virtual terrain and any (DIS) entities in the virtual environment to produce appropriate ISR imagery and GMTI data.

5 A High-Fidelity Training Simulator

The UAV Sensor Suite ISR imagery and GMTI data produced in the required standard format will be used to *stimulate* the same (COTS) exploitation software that is used in the Global Hawk Mission Control Element. Stimulating the real Global Hawk Mission Control Element exploitation software reduces (traditional) concurrency training problems considerably.

The Global Hawk Mission Control Element, sensor data and image processing operator can view selected images for a “quick look” evaluation. This may result in a dynamic mission update that must conform with required tasking and clearances. These mission updates can range from re-tasking a sensor for a single image through re-planning the entire mission plan including modification of the flight plan, sensor plan, and data dissemination plan.

Imagery may be processed and mosaiced prior to display and/or dissemination and may also be transmitted directly to other remote Mission Control Elements or systems with EO/IR and/or SAR processing capabilities able to process Global Hawk data.

Data from the ADGESIM Global Hawk UAV simulator can be disseminated into the real ADF network as if the data were real Global Hawk data.

Because the ADGESIM UAV ISR data *stimulates* the same (COTS) exploitation software that is used in the real Global Hawk Mission Control Element (MCE) the ADGESIM Global Hawk UAV simulator can be considered as a *high-fidelity*, *training* simulator for MCE

sensor data and image processing operators and other Global Hawk data intelligence operators.

6 An Experimentation Simulator

Initially the ADGESIM Global Hawk UAV simulator will be coded to emulate the exact functionality of the Global Hawk UAV as closely as possible. However the UAV simulator can be used to demonstrate or investigate additional or alternative capabilities.

Some simple examples are:

- The ADF may wish to investigate the performance of the COTS Global Hawk SAR system compared to an alternative, full coverage, 360 degree SAR system. This could be done *experimentally* by alternatively "flying" the UAV simulator in a typical scenario using both the standard COTS, and a recoded 360 degree SAR systems and comparing the results;
- UAVs will have to share the air space with commercial aircraft. The ADGESIM UAV simulator could be used in a virtual environment to *experimentally* investigate the effectiveness of collision avoidance algorithms; and
- New, innovative Global Hawk ground station elements or components could be designed and *experimentally* tested using the correctly formatted EO/IR, SAR and GMTI data obtained from the ADGESIM UAV simulator.

The ADGESIM UAV simulator could be used to improve the usefulness of the real UAVs as the ADGESIM Global Hawk UAV simulator can (also) be used as an *experimentation* simulator.

7 Advanced Distributed Simulation Interoperability

Because IEEE 1278.1A DIS is used as the backbone protocol of the ADGESIM Global Hawk UAV simulator the simulator can be connected into any coalition/ADF/RAAF DIS network that includes other DIS applications, training simulators and/or real platforms.

Additional capability can be provided using cost-effective, COTS, distributed simulation applications. For example:

- If a complex training scenario is required this capability could be easily provided by connecting a COTS, DIS, Computer Generated Forces package to the DIS network; and
- HLA and/or TENA interoperability can be achieved using appropriate COTS gateway applications.

8 Summary and Conclusions

The following summarises the objectives, conclusions and the lessons learned from the work done on the ADGESIM Global Hawk UAV simulator proposal:

- The proposed ADGESIM Global Hawk UAV simulator will provide an experimental capability to develop tactics, techniques, procedures and concepts of operations for the intelligence collection system that the UAV simulator simulates and the broader ADF system that the (simulated) Global Hawk UAV would be part off;
- The ADGESIM Global Hawk UAV simulator is not proposed to provide training for (i.e. provide high-fidelity replication of the functions carried out by) the Global Hawk mission planning operator, the air vehicle operator, and the communications control operator;
- Initially the proposed UAV simulator will concentrate on the functionality carried out at the MCE Sensor Data Control and Image Processing Station (ie obtain, view, process and disseminate sensor imagery) as this is the output product of a Global Hawk UAV. In this domain the ADGESIM Global Hawk UAV simulator is capable of providing high-fidelity training;

- A considerable part of the ADGESIM Global Hawk UAV simulator has already been developed because many of the generic ADGESIM components that are already used operationally to train RAAF Air Defence Controllers will be reused in the ADGESIM Global Hawk UAV simulator;
- The proposed UAV simulator will model the Electro-Optical, Infrared, Synthetic Aperture Radar and Ground Moving Target Indicator capabilities of a typical "Global Hawk like" ISR payload;
- The proposed UAV simulator will support interoperability standards and will therefore be capable of participating in distributed simulation exercises that includes coalition, ADF and/or RAAF simulators and/or real platforms;
- The proposed UAV simulator will disseminate ISR imagery and GMTI data using exactly the same formats as are used by the real Global Hawk UAV. Therefore any system that interacts with real Global Hawk UAV imagery or GMTI data can be stimulated by the ADGESIM Global Hawk UAV simulator;
- The proposed UAV simulator is a stimulated (ie high-fidelity) system thereby reducing concurrency (the difference between the simulator system and the real system) problems;
- The proposed UAV simulator is based on PC technology;
- The proposed UAV simulator uses COTS or GOTS where possible;
- Because the proposed UAV simulator is based on PC technology and is mainly COTS/GOTS it will be low-cost and cost-effective to purchase, develop and maintain; and
- The proposed UAV simulator will be portable and deployable.

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