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Tactical Aviation Mission System Simulation Situational Awareness Project

Final Report

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Abstract

This document reports on the Department of National Defence (DND) Tactical Aviation Mission System Simulation (TAMSS) Situation Awareness (SA) project. The TAMSS SA project was conducted at the Centre for Applied Cognitive Research (CACR) at the Carleton University. In accord with the original goals of this project, the deliverables included the development of a CH146 Griffon simulation capability at the CACR, the development of a theoretical framework to guide the evaluation process, three experiments that both assessed an engineering system and a theoretical framework, and this document, which summarizes the TAMSS SA project and provides a link to acquisition programs and to potential simulation-based training applications.

The TAMSS SA project provides a guide for the implementation of simulation-based evaluation on a cost-effective platform. The combination of the CSE framework and the research-enabling simulation environment that was developed in the TAMSS SA project can be used to reduce risk and enhance value in acquisition programs. Collaboration among the Carleton University CACR researchers, including graduate students, and from the visits from many DND personnel, subject matter experts, and industry representatives, has demonstrated the value of locating these activities in a research-rich environment.

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Executive summary

Introduction

This document reports on the Department of National Defence (DND) Tactical Aviation Mission System Simulation (TAMSS) Situation Awareness (SA) project. The TAMSS SA project was conducted at the Centre for Applied Cognitive Research (CACR) at the Carleton University. In accord with the original goals of this project, the deliverables included the development of a CH146 Griffon simulation capability at the CACR, the development of a theoretical framework to guide the evaluation process, three experiments that both assessed an engineering system and a theoretical framework, and this document, which summarizes the TAMSS SA project and provides a link to acquisition programs and to potential simulation-based training applications.

Carleton University CH-146 Simulation Environment.

The Carleton University CACR CH-146 simulator was developed as a modified version of a TAMSS Networked Tactical Simulator (NTS). The CACR simulator provides state-of-the art capabilities for experimentation and data collection. The simulator includes an out-the-window display, a helmet mounted display, head-tracking capabilities, a scenario generation utility, and custom data collection capabilities. In addition, an Electro-optical Reconnaissance, Surveillance, Targeting and Acquisition (ERSTA)-like simulation model was integrated into the CACR simulator environment using high-level architecture (HLA). The CACR simulator is an effective platform for prototyping and exercising human-machine systems and for measuring the impact of new technologies in a dynamic simulation environment.

Theoretical Framework: Cognitive Systems Engineering.

A survey of existing literature on experimental approaches to evaluating modelling and simulation allowed the development of a Cognitive Systems Engineering (CSE) framework that combined three central constructs in the field of human-machine collaboration: situation awareness, workload, and task-relevant performance. Workload refers to the cognitive effort required by the operator, situation awareness refers to the operator's ability to represent and monitor the ongoing activity, and task-relevant performance refers to the specific aspects of the operators' behaviour that relate to the machine being evaluated. All three aspects of the human-machine system can be evaluated objectively and subjectively (the latter from the perspective of the operator). Objective measures of performance can include head position, aircraft characteristics such as heading, speed, and altitude; of situation awareness – detection of relevant objects in the environment; of workload – response to visual or auditory cues. Subjective measures include ratings (Likert type and NASA TLX measures were both used) of situation awareness, performance, and workload. Various combinations of these measures (with at least one of each category) were used in each of the three experiments.

Experiments.

In three experiments, the usefulness of the CSE framework for evaluating human-machine systems was demonstrated. In Experiment 1, pilots showed reduced situation awareness and increased workload when they were using night vision goggles. In Experiment 2, ERSTA-like sensor capabilities, combined with a digital moving map, allowed aircrew to have enhanced situation awareness and at times reduced workload. In Experiment 3, the presence of an mission specialist to operate an ERSTA-like system allowed the mission commander to have increased OTW viewing time, substantially decreased workload (both objective and subjective), and enhanced situation awareness. All three experiments used experienced flight crews, and realistic missions. The findings supported the use of the CSE framework for modelling and simulation and for simulation-based acquisition programs.

CSE-Based Modelling and Simulation for Acquisition.

The CSE framework that was developed in the TAMSS SA project provides a structure for three modelling and simulation activities: design, rapid prototyping and simulation-based evaluation. For design and rapid prototyping, the constructs in the CSE framework orient activity toward consideration of how the human-machine system will potentially affect operator SA, workload and task-relevant performance. For simulation-based evaluation, the CSE framework provides both a conceptual structure and strong methodological guidance.

Integration into Simulation-Based Training.

Throughout the conduct of the work associated with the establishment of a CH-146 simulation environment at the Carleton University CACR, as well as throughout the conduct of experiments, it became readily apparent that NTS-like devices had the potential to serve a far broader range of applications than those exercised during the performance of the TAMSS SA project. Comments from industry, government and subject matter experts suggested that upgraded NTS-like devices be used to augment Part-Task Training (PTT), Cockpit Procedures Training (CPT), Tactics Training and Mission Rehearsal requirements. It is concluded that NTS-like systems could contributed to a vertically integrated training solution, such as that represented by the Integrated Simulation Training System (ISTS) concept currently circulating within the Canadian Forces.

Conclusions

The TAMSS SA project provides a guide for the implementation of simulation-based evaluation on a cost-effective platform. The combination of the CSE framework and the research-enabling simulation environment that was developed in the TAMSS SA project can be used to reduce risk and enhance value in acquisition programs. Collaboration among the Carleton University CACR researchers, including graduate students, and from the visits from many DND personnel, subject matter experts, and industry representatives, has demonstrated the value of locating these activities in a research-rich environment.

Herdman, C. M., LeFevre, J. 2004. Tactical Aviation Mission System Simulation Situational Awareness Project. Defence R&D Canada.

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1. Project Overview

1.1 Major Tasks

This document reports on the Department of National Defence (DND) Tactical Aviation Mission System Simulation (TAMSS) Situation Awareness (SA) project. The TAMSS SA project was conducted at the Carleton University Centre for Applied Cognitive Research (CACR).

Two major activities were completed in the TAMSS SA project. The first major activity was to establish a research-enabling CH-146 simulation environment at the Carleton University CACR. The second major activity was to conduct three graduate-level research studies on Situation Awareness (SA).

1.1.1 Carleton University CACR CH-146 Simulation Environment

The first major task in the TAMSS SA project was to establish a research-enabling CH-146 simulation environment at the Carleton University CACR (see Figure 1). This task was accomplished using a modified version of a TAMSS Networked Tactical Simulator (NTS) device that included an Out-The-Window (OTW) display, a Helmet Mounted Display (HMD), head-tracking capabilities, a scenario generation utility, and custom data collection capabilities. In addition, an Electro-optical Reconnaissance, Surveillance, Targeting and Acquisition (ERSTA)-like simulation model was integrated into the CACR simulator environment using high-level architecture (HLA).

The Carleton University CACR CH-146 simulation environment was developed across the extent of the TAMSS SA project. This cost effective and malleable environment was proven to be an effective platform for prototyping and exercising systems and for measuring the impact of new technologies in a dynamic simulation environment. A full description of the Carleton University CACR CH-146 simulation environment is given in Section 2.1.1.

Figure 1 - CACR CH-146 Simulation Environment

1.1.2 Three graduate-level studies

The second major task in the TAMSS SA project was to conduct three graduate-level studies on SA. The intent of the studies was to develop and document methods for measuring SA in a simulation environment.

An analysis of the research literature showed that human-machine interactions are often too complex for a single concept (such as SA) to provide sufficient information regarding the impact of an interface on an operator's overall behaviour. Accordingly, a broader Cognitive Systems Engineering (CSE) framework was developed that combines three central constructs in the field of human-machine collaboration: situation awareness, workload, and task-relevant performance. Situation awareness refers to the operator's ability to cognitively represent, monitor and predict activities, workload refers to the cognitive effort required by the operator, and task-relevant performance refers to the specific aspects of the operators' behaviour that relate to the system being evaluated. The CSE framework was used to guide investigations in the three TAMSS experiments.

The effectiveness of the CSE framework was examined and proven in the three TAMSS experiments. In all three studies, trained CH-146 aircrews were required to complete simulated missions (e.g., reconnaissance) in the Carleton University flight simulator. In Experiment 1, CH-146 pilots showed reduced situation awareness and increased workload when they were using a heads-up display. In Experiment 2, ERSTA-like sensor capabilities, combined with a digital moving map, allowed CH-146 aircrew to have enhanced situation awareness and at times reduced workload. In Experiment 3, it was shown that the presence of an mission specialist to operate an ERSTA-like sensor system allowed the CH-146 mission commander to have increased OTW viewing time, substantially decreased workload (both objective and subjective), and enhanced situation awareness.

The three studies in the TAMSS SA project unequivocally show that the CSE framework provides an effective guide for assessing human-machine systems in a simulation-based environment. The effectiveness of the CSE framework is enhanced when an evaluation includes at least one, and preferably multiple measures of situation awareness, workload, and of task-relevant performance. The use of multiple measures will allow for a richer and more accurate index of how new technologies affect the human-machine interaction. As discussed in Section 2.2, the CSE framework can provide an effective structure for simulation-based evaluation activities in DND acquisition programs.

2. TAMSS SA Project Activities

2.1 Carleton University Simulation Environment

A major activity in the TAMSS SA project was to develop a research-enabling CH-146 simulation environment at the Carleton University CACR lab. This activity spanned across the full TAMSS SA project.

2.1.1 Overview

The flight simulator at Carleton University is a custom version of the Networked Tactical Simulator (NTS) that has been developed by The HFE Group, Inc. as part of the TAMSS initiative. As with other NTS systems, the Carleton NTS represents the flight deck, mission equipment, and physical structure of the CH-146 Griffon helicopter flown by the Department of National Defence (DND). The Carleton simulator includes both out-the-window (OTW) and Helmet Mounted Display (HMD) capabilities. The Carleton simulator has a head-tracker to support the use of the HMD. Additionally, the simulator supports the creation of synthetic environments and scenario creation via staging software.

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 pilots flying the simulator.

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. As well, the INSTR1 PC hosts the custom data collection software used in the Carleton experiments. Finally, the sixth PC, the Experimenter Operating Station (EOS), is responsible for overall system control, including mission loading and unloading. As well, this PC 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. Figure 2 and Figure 3 provide a general overview of the hardware, functionality, and communications infrastructure of the Carleton NTS.

2.1.2 Simulation Hardware

The following summarizes the main components of the Carleton NTS. The six PCS in the Carleton simulator are equipped with dual Pentium III 1GHz processors. Each machine has 1 GB of RAM. The machines are physically networked using a 3Com SuperStack 3 Baseline 10/100 12 port Ethernet Switch. Three NEC Model MT1055 Data Projectors are used to project generated images (using Vega software) on 8'x 6' screens, creating the immersive out-the-window scene. The head-tracking system used is an Intersense IS-900 Virtual Workbench Tracking System. The IS-900 is a 6 degrees-of-freedom tracker, tracking both position and angular changes (X, Y, Z, Heading, Pitch and Roll). The IS-900 provides position resolution of 1.5mm in position and an angular resolution of 0.05 degrees. It is jitter-free with a position stability of 4 mm and angular stability of 0.2, 0.4 RMS. For a detailed depiction of the hardware configuration of the Carleton simulator, refer to Figure 3.

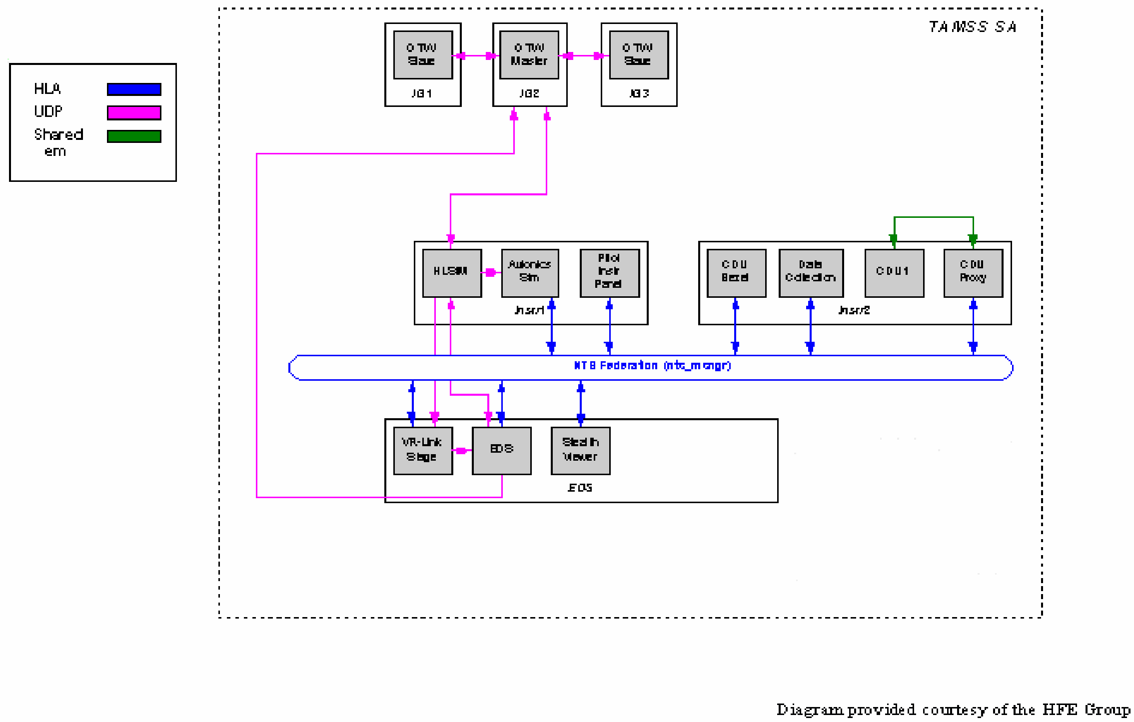

Figure 2 - Carleton Simulator General Overview

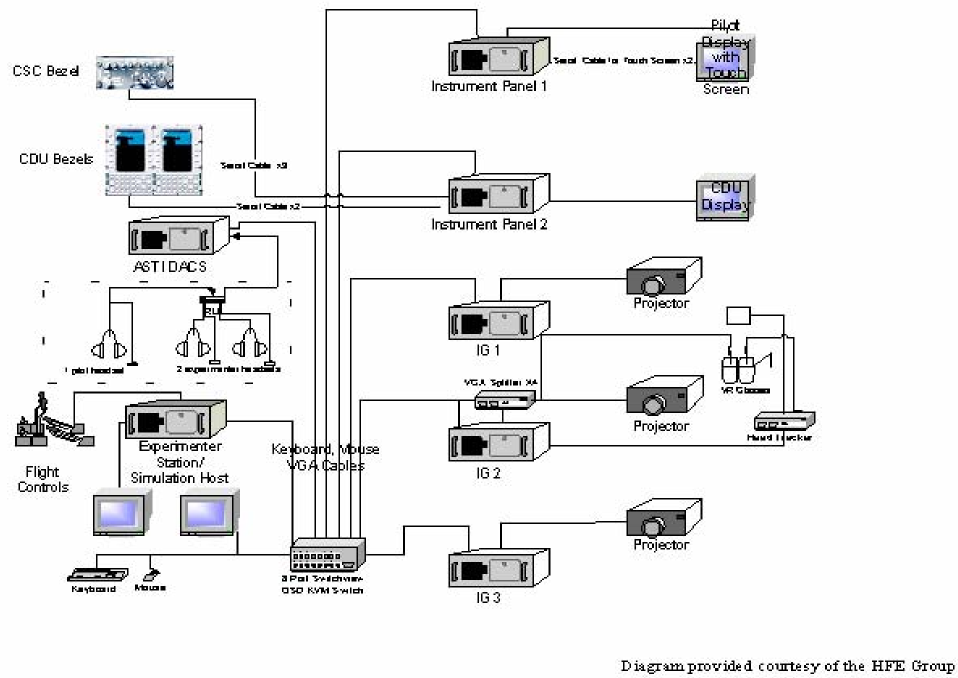

Figure 3 - Carleton Simulator Hardware Overview

2.1.3 Software Overview

2.1.3.1 COTS Products

The simulator 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 Virtual Prototypes Incorporated, 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' situation 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 situation 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 STAGE’s HLA is not enabled, STAGE communicates only with the other 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.

2.1.3.2 Custom Software Code

Custom code within the Carleton simulator is used for the Experimenter Operator Station (EOS). EOS is responsible for the command and control of various components as well as for the unique-to-Carleton experimental and data logging capabilities. A more detailed description of the EOS capabilities is given in the next section. Custom code is also used to develop the HMD symbology generation capabilities.

Other components that use custom code are the avionics simulation module, the pilot Head-Down Display (HDD) instrument panel, the CDU bezel and CDUs, and the HUD symbology. The Communications software within the simulator, whether via HLA, UDP or Shared Memory is also custom code. Tools used in the development of the custom code include VAPS by Virtual Prototypes Incorporated (CDU), GLStudio (pilot head-down instrument panel and HUD symbology) by DiSTI, and VR-Link (HLA) by MÄK Technologies.

2.1.4 The Experimenter Operator Station (EOS)

The EOS encapsulates control functions for the Carleton simulator as well as the experimental capabilities are unique to the Carleton CACR simulation system.

2.1.4.1 Command and Control Capabilities of the EOS

The control functions of the simulator are accessed via a GUI interface. The main control functions are as follows:

1. The Mission Control function opens, loads, resets, unloads and exits missions.

2. The Location function allows for console control of the aircraft position. It has a slew mode in which the operator can move the aircraft in all cardinal directions as well as change the aircrafts altitude and heading.

3. The Weather function changes atmospheric conditions such as wind direction, wind speed and cloud cover in the OTW scene.

4. The Ownship function can be used to alter the ownship fuel levels, communications and navigation settings.

5. The Options function currently enables the operator to change the date and time at which the mission is taking place. The Vega generated scene will accordingly adjust lighting when these are changed.

6. The Communications function enables the operator to monitor and transmit on a specified frequency via the Digital Audio Communication System (DACS). It also has an intercom capability.

7. The Freeze function allows the operator to freeze the aircraft, the scenario or both (freeze all).

8. The System Control function gives the operator some degree of remote control over the PCs in the network. It supports system Reboot, Reboot IGs, and system Shutdown capabilities.

2.1.4.2 Experimental Capabilities of the EOS

The experimental capabilities of the Carleton simulator make it different from the average flight simulator. The Carleton system has the ability to generate events, log pilots' responses to events, and log key flight-related data throughout a mission. This data can then be used to assess pilot performance, workload and situation awareness.

The experimental software has three major components: Experiment Scenario Generation, Experiment Control, and Data Collection. The interplay of these three components is shown in Figure 4.

2.1.4.3 Experiment Scenario Generation

The Experiment Scenario Generation creates an experimental scenario by defining a list of events that are to occur during the course of the mission. The system currently supports the generation of audio and visual events. Audio events generate a tone of specified frequency and duration using the DACS. Visual events generate an image that is displayed in Vega for a specified duration of time. The experimenter can set the onset time, timing mode (periodic or on-shot events), as well as the duration of the probe. For periodic timing, the experimenter specifies the period interval as well as the variance in interval time. For visual events, the experimenter can also specify the reference point (e.g., Head, Aircraft, or World reference), as well as the relative position to the frame center (e.g., X, Y, Z, Heading, Pitch, Roll) at which the event should appear.

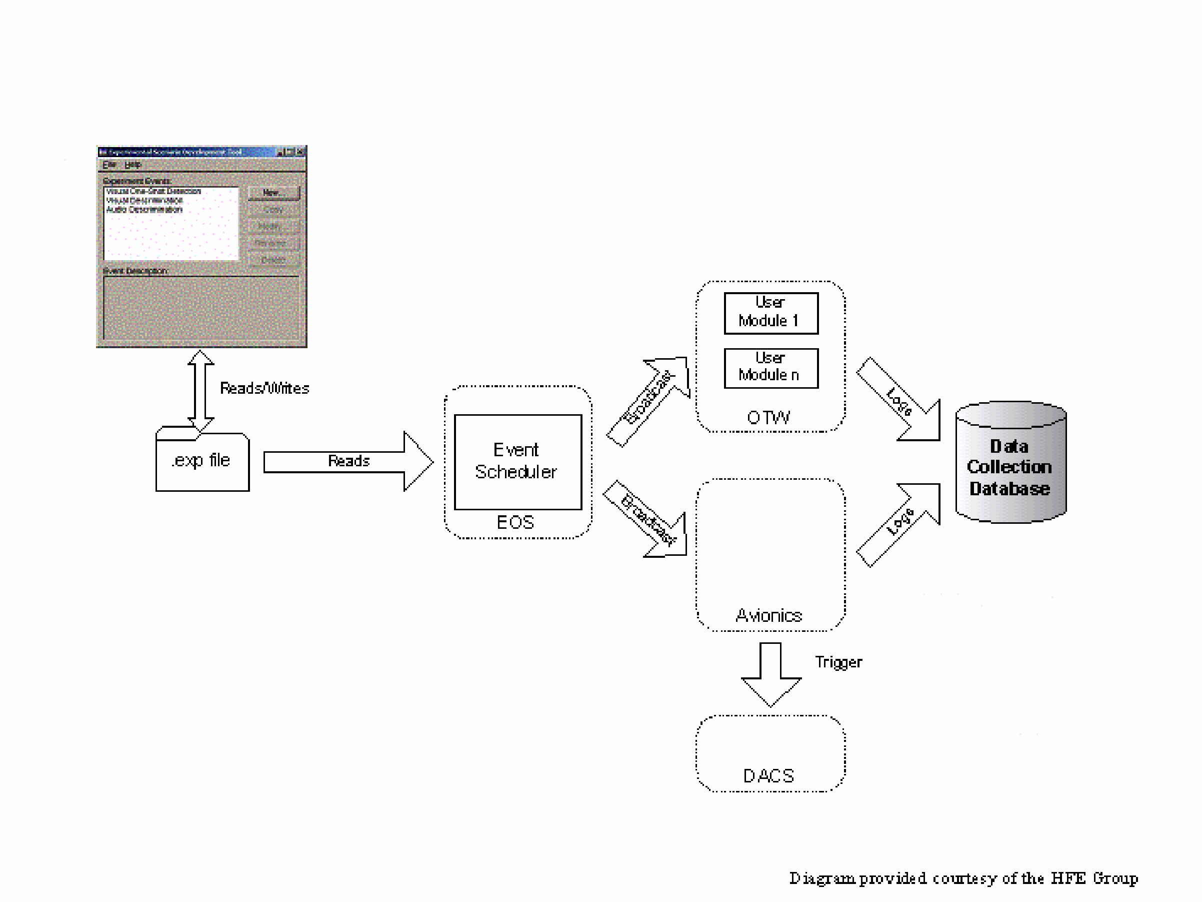

Figure 4 - Experiment System Overview

There are two types of tasks associated with the event, detection and discrimination, which are currently supported by the system. In the detection task, the pilot's task is to detect audio or visual stimuli and respond as quickly as possible to the stimuli, usually by pressing a button. In the discrimination task, the pilot's goal is to identify a specific object out of a range of objects, using a TRUE/FALSE type of response. The user is able to specify the number of objects to be used in the experiment as well as the weighting of TRUE to FALSE responses.

Once all the events have been specified, the experimental scenario is saved as an ".exp" file, and the experiment is ready to be launched.

2.1.4.4 *Experiment Control*

Experiment Control launches the experimental scenario and is used to initiate the data collection process once the desired ".exp" file has been selected by the experimenter. A graphical interface enables the user to select, launch and stop an experimental scenario. The EOS feeds information from the ".exp" file to an event scheduler which initiates the audio and visual events at the designated times. Experiment Control also contains a head tracker calibration utility.

2.1.4.5 *Data Collection Capabilities*

Data Collection is a background process that starts automatically when the experiment is launched. The Data collection application logs the following information:

1. Session information: Session ID, Start Time, End Time, Subject Number, Trial Number

2. Audio Events: Session ID, Simulator Time (of event), Task Type, Event Duration, Truth Value, Is_Target (in discrimination task), Tone Frequency

3. Visual Events: Session ID, Simulator Time (of event), Task Type, Event Duration, Truth Value, Is_Target (in discrimination task), Object Number, Reference (Head, Aircraft, World), X, Y, Z, H, P, R

4. Button Press: Session ID, Simulator Time (of button press), Button Number Pressed

5. Head-tracker Data: X, Y, Z, H, P, R (Positional and Angular information)

6. HELISIM Data: Session ID, Simulator Time (of data) plus 99 other parameters derived by HELISIM. The most important of these for experimental purposes are: Latitude, Longitude, Altitude, Speed and Heading.

The above items are logged in separate SQL tables and can be examined and extracted using a Microsoft Access application as a front-end to the database.

2.1.5 Experimental Features Added

In addition to the experimental features provided by The HFE group, the CACR has successfully added several new experimental features to the simulator. These include add-ons and upgrades to The HFE Group's original applications, as well as new applications allowing for new experimental designs and measurement. This section will briefly review these features.

2.1.5.1 Freeze HDD instruments

An application has been developed to give the operator of the experiment the ability to freeze at any given moment any of the following indications displayed on the HDD: Air speed, Heading, Radar Altitude, Barometric Altitude and Torque. This feature also records the time at which the freeze command was initiated, allowing the experimenters to refer to this information at a later time. This feature also provides the operator with the ability to remove and replace the entire HUD display upon command.

2.1.5.2 Attitude recovery task

Although not used in the TAMSS SA experiments, a complete attitude recovery task was created. The task consists of blanking the screen, placing the aircraft at a pre-configured attitude, then un-blanking the screen and passing control to the pilot. The pilot is then instructed to indicate their completion of recovery by pressing one of the cyclic buttons. During the recovery process, numerous data are recorded (in addition to aircraft attitude) including the time at which the scene was un-blanked and control was passed to pilot and the time at which the pilot indicated task completion.

This application also allows for the task difficulty to be controlled by the experimental operator. This control can be achieved by controlling/configuring the initial aircraft attitude and by controlling/configuring the turbulence at the area where the task takes place. In addition, the following task parameters can be configured by the experimental operator through the use of a task configuration table (a simple text file): Air speed, Altitude, Heading, Pitch, Roll, Torque (this is optional in cases when inexperienced pilots are being used), Turbulence (vertical air speed, horizontal air speed, period of cycles).

2.1.5.3 Cyclic button press recording and filtering

A simple filtering mechanism has been added to clear the noise that is recorded when a pilot presses and holds down the cyclic button for a long period of time. A thread was added to allow for a cyclic button press sampling rate of 5 ms. This sampling rate can be adjusted as necessary.

2.1.6 General Additions and Upgrades

An interface for HELISIM was added to the CACR simulator to allow developers to fly the aircraft from the development station using a simple joystick while using/monitoring other tools at the development station. The addition of these experimental features allows the CACR team to measure the SA of pilots under several new conditions (i.e., when the HUD or HDD freezes, or when they must recover after losing control of the aircraft). These measures will assist in the definition and measurement of SA.

2.1.7 Data Collection: Evaluation and Testing

The Carleton simulator is used for experimentation, and thus it is important to determine the amount of time delay occurring between a pilot's action or response in the simulator and the logging of this response by the experimental software. Ideally this delay will be minimal so that the simulator mimics real-time events as closely as possible. Furthermore, the amount of time that it takes for information to pass through the system to the EOS should be consistent over time to ensure that the measures being sampled are accurate. The next section describes the tests that have been performed by the CACR in an attempt to measure the time delays occurring within the Carleton simulator.

2.1.7.1 UDP packet delay measures

The CACR engineers have taken measurements to determine the amount of time required to transfer a single UDP/IP packet between two applications running on two separate PCs. UDP/IP packets are the main data transfer mechanism used by the simulator. They are used both for direct communication between the several modules that make up the simulator system and as a transport layer for “over HLA” communication. The delay of a single small UDP packet sent between two applications running on two separate machines was measured by the CACR. This measurement was gained using loop-back methodology and was based on the internal Windows clock giving a resolution of 1ms. It was found that the measured delay in a loaded system at a steady state (while executing standard Out the Window scene) is always less than 2 ms.

2.1.7.2 Serial port loop-back delay

The delay between the writing and the reading of a single ASCII character through the PCs serial port was measured by means of an external loop-back. When a single ASCII character is written to one of the PC's serial ports, it triggers the digital scope. The digital scope is used for several timing/delay measurements in a system.

In order to perform this measurement, the Tx pin of the serial port was shortened externally with the Rx pin. Then, a Windows application was used to send a single character (8 bit) at 115600 bits/sec using the standard Windows WriteFile() call and receive the character using the standard Windows blocking ReadFile() call. The delay between the two calls was measured using the internal Windows clock with a resolution of 1ms. The measured delay between the two calls was found to be less than 2 ms. This measurement gives us an indication of the interaction delays in our system between the application layer and the hardware layer. These interactions are carried out by the Windows device drivers.

2.1.7.3 Vega timing (for post-draw rendering)

This measurement was taken to determine the amount of delay that occurs between the time that an object is added to the post-draw function in Vega and the time at which the object appears on the projection screen. The last stage at which Vega can execute a user code before the display buffers for the current frame are swapped and then displayed, is during the post-draw callback stage. The user can add visual objects such as the HUD symbology or any other visual objects at this stage. The CACR team measured this delay using the following process:

1. A method that blanked the scene (the display buffer) was called.

2. A method to draw a small bright (white) rectangle at the top of the scene was called.

3. A signal to trigger a two-channel digital scope was sent through the serial port to the scope.

4. Control was taken by Vega that swapped the display buffer.

This process allowed transmission the photo diode that was connected to the second channel of the digital scope through an amplifier to send a signal to the scope as soon as the bright rectangle appeared at the top of the screen. The delay between the time that an object was added as a post-draw object and the time that it took to appear at the top of the screen (in this case as a white rectangle) was 28 ms (±1ms). When the same bright rectangle was moved to the bottom of the screen, the measured delay was 44 ms (±1ms) that is, 28 ms + 1/60 Hz. It is important to note that the delay between the end of the post-draw stage (that is under the user's code control) and the time when the actual image starts to appear at the top of the screen should remain constant regardless of the amount of displayed data.

2.1.7.4 Cyclic button press delay

The latency between a button press on the cyclic and the time it takes to receive this response at the PCI based A/D board was measured. In the SA Experiment 1, a button press on the cyclic was used by the pilots in response to stimuli that were presented as part of the scenario. Originally the pilots' controls (including the cyclic buttons) were sampled by HELISIM at a rate of 60 Hz, meaning there was a minimum delay of 16.66 ms. A separate thread has been added by the CACR to make the sampling rate independent of HELISIM. This has allowed for a sampling rate much faster than 60Hz. In future applications, the delay will be re-measured with the addition of this new thread. Sending a character through one of the serial Tx pins and connecting it externally to one of the discrete inputs on the A/D board will gain this measure. The time difference between the call to WriteFile() and the time that a change in the state of the discrete input is sensed by the thread will be measured using the Windows clock.

2.1.7.5 Time synchronization mechanism

A time synchronization mechanism to synchronize the 6 PCs in the simulator has been implemented. This mechanism consists of a timeserver that executes on one of the PCs and time clients that periodically (at ten second intervals) send time synchronization requests to the server. These time clients also receive updated time responses that are used to set their PC's internal clock.

As part of this process, half of the travel delay (the time between sending the sync request and receiving the time sync replay) is subtracted at the client side to compensate for the communication delay between the client and the server (if the measured round trip delay is longer than 4 ms the clock is not getting updated during that cycle). A UDP/IP packet with a delay of less then 2 ms was sent between the PCs to determine the degree of synchronicity between the PC clocks. The clock synchronization in the system was found to be ±2ms. This mechanism can be used to obtain accurate response measurements in the system, especially when an event is initiated by an entity executing on one machine while the response for the event is accepted by an entity executing on a different machine.

2.1.8 Data Collection in a Distributed Environment

Data collection in a distributed simulation environment brings to bear a number of issues. These are discussed below.

2.1.8.1 Architecture of distributed data collection system

In the TAMSS experiments, a distributed data collection architecture was developed as shown in Figure 5. All data is collected on a single machine and logged into a standard SQL data base. Each of the data generating/sampling tasks sends data over a UDP/IP socket to the data collecting process at it's own pace. The data collecting process consists of 7 threads, one per each sending process. Each thread is blocked on it's receive socket until a packet with data to be logged arrives. As soon as the data arrives, it is time-stamped based on the internal clock on the INSTR2 machine and then written into the SQL data base. Beside each data record that is represented as a row in the relevant table, there is a column to store the time stamp (in milliseconds) for that row. The time stamp represents elapsed time since the beginning of the data collection session.

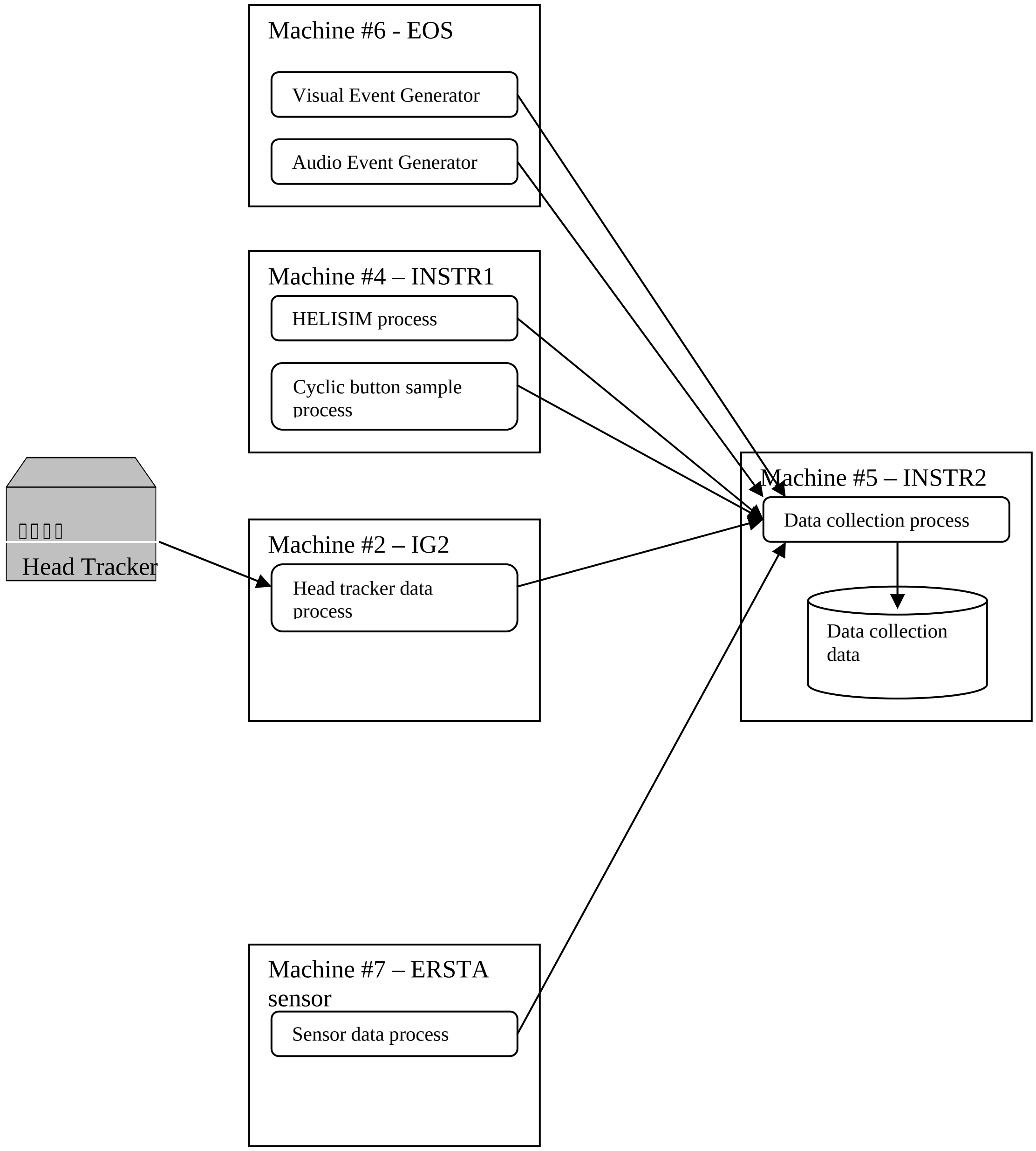

Figure 5 - Data Collection in a Distributed (HLA) Architecture

2.1.8.2 Fidelity of timing for the logged data

Referring to Figure 6, assume that a participant presses a response key at time t_{press} to indicate that she/he had detected an event (e.g., audio or visual probe) that had occurred at time t_{event}. The response keys are sampled periodically at 60Hz, thereby implying a delay of up to 1/60 seconds (16.66ms) between the actual key press and the time the key was sampled, hence $d_{sample} < 16.66$ms.

At this stage, data is written to the sending socket and is being queued until the operating system's kernel (Windows) sends it over UDP to the data collecting machine. This delay is d_{qsend}, and is hard to measure directly. The data packet is transmitted by the Windows network driver over Ethernet through the local switch to the data collecting machine. The transmission delay for a small packet is $d_{Ethernet}$ and is typically very short when a 100Mb Ethernet is used. The packet is received at the data collecting node by the Windows network driver and is being queued until the data collection process is scheduled by Windows. This delay is $d_{scheduling}$ and is typically < 20ms. Based on measurements using a digital scope and two Windows 2000 machines (a loop back test), $d_{network}$ is the sum of d_{qsend}, $d_{Ethernet}$ and $d_{scheduling}$ < 22ms. As soon as the packet is received by the data collecting thread, the internal hardware clock is sampled in order to assign a time stamp to the data. It takes up to 20ms to acquire the time (regardless if it's the time of the day clock or the better resolution multimedia clock) $d_{timestamp}$. This delay is due to the fact that a request to access the clock is queued by Windows and only the Windows kernel can access that clock and return the result to the requesting process. All the above sums to a maximum delay of $d_{sample} + d_{network} + d_{timestamp} < 58.66$ms which is the worst case resolution for the timing data. For data collection from HELISIM or from the head tracker, d_{sample} can be ignored and hence the resolution is at 42ms.

2.1.8.3 Database

A relational data base (MySQL) was used to store collected data in the TAMSS simulation system. This is the most popular database storage structure in general use. Microsoft Access was used to access MySQL data through an ODBC adaptor using the "C" programming language. During the TAMSS SA experiments, failures with the provided ODBC adaptor resulted in some data loss. These failures were corrected in the later experiments.

2.1.8.4 Collected data

Data is collected from the following sources during a simulation run:

1. HELISIM. Data such as position, orientation, velocity and other flight dynamics parameters of the flight simulator were sampled and logged at 60Hz.

2. Head tracker data. Pitch, roll, yaw, x, y, z values of the head mounted sensor were sampled at 30 Hz.

3. Cyclic buttons and other response keys. All of the cyclic buttons plus a foot switch were sampled at 60Hz

4. ERSTA sensor. The ERSTA sensors control modes, orientation, FOV, zoom, etc., were sampled at 60Hz.

5. Auditory and visual events for generation of work load were recorded immediately after generation.

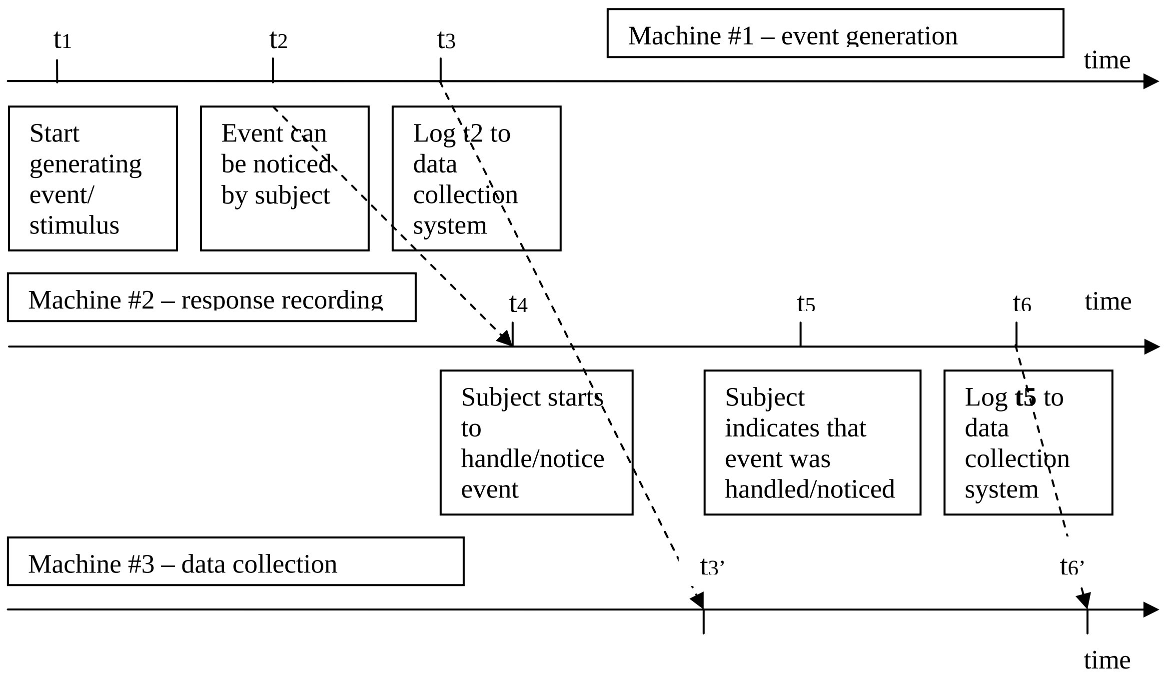

Figure 6 - Response Time Capture

2.1.8.5 *Recommendations for future systems*

The main advantage of the current architecture for data collection is its simplicity and flexibility. It is a relatively straight forward to add a data collection module to collect new data items from a new module such as ERSTA. When compared to other possible architectures such as the usage of HLA for data collection, the current architecture probably generates the least network traffic possible due to the smallest possible overheads and hence small and optimized data packets. The lean network traffic should contribute to minimization of network delays between the participating nodes in the simulation.

The most evident disadvantage is the relatively low fidelity of the timing mechanism where the worst case resolution was around

60ms, and this was calculated for a LAN environment. If the different components of the simulator were to communicate over WAN, as is intended for future systems, the dnetwork component of the delay could have been at the magnitude of hundreds of milliseconds. Another disadvantage of the current architecture is that it cannot provide enough data and would not provide it in such a way that the data could be used to capture the flow of an exercise or even single events or states associated with the participating entities that take place during the simulation. The following means can be used in order to improve the low fidelity of the timing:

1. Events can be time stamped at the originating node rather then at the data collecting one, this will eliminate $d_{network}$ but will require a time synchronization mechanism between the nodes.

2. By switching from Windows to an operating systems such as Linux or a Real Time Operating System (RTOS)), $d_{timestamp}$ can be easily reduced to less than 1ms because of the ability for user applications to call the time services directly rather than by placing a request to the kernel. d_{sample} can be reduced if required but this will usually involve hardware implementation (H/D interrupts by the A/D hardware instead of periodic polling).

If there is a requirement for capturing the flow of events and states during a simulated exercise for the purpose of review or replay, then HLA protocol would be a natural candidate for interconnection between the different modules of the simulation. All public data can be captured by a data-collecting federate that is subscribed to all the relevant attributes and interactions. For the purpose of capturing private data, the FOM would have to be expended so that private data could be captured as well by the data collecting federate.

2.1.9 Integration of an ERTSA-Like System into the CACR Simulation Environment

A simulation model of the DND Electro-optical Reconnaissance, Surveillance, Targeting and Acquisition (ERSTA) system was required for Experiments 2 and 3 of the TAMSS SA project. To this end, a simulation model and a sensor operator station was modified by CMC Electronics Inc. and integrated into the CACR simulation environment (see Annex A and Annex B). The operator station was previously developed as a mock-up to conduct human factors experimentation of the operator station using an aircraft FLIR system.

It is important to note that because the ERTSA system had has not been purchased for the CH-146 fleet within the timeframe of this contract, the ERSTA representation that was used in the TAMSS SA project was intended only as generic representation. Accordingly, although an attempt was made to represent the general functionality of the anticipated ERSTA system, the full capabilities of ERSTA system were not represented in the TAMSS SA project. Of particular note was that (a) the range and fidelity of the simulated sensor system (camera imagery) was approximately 40% that of the anticipated ERSTA system and (b) the displays and controls that were used in this project were not selected as prototypes for the anticipated ERSTA system. For these reasons, the ERSTA model that was used in the TAMSS SA project is heretofore referred to as the ERTSA-like model.

A description of the ERTSA-like model operator station that was used in Experiments 2 and 3 of the TAMSS SA project is given in Annex A.

2.1.9.1 Functionality of the ERSTA-like system

The ERSTA-like model that was used in the TAMSS SA project included:

- A sensor simulation model to simulate a Color Day Television (CDTV) System.
- A virtual scene display to simulate real-time video displays of sensor imagery.
- A tactical map display to show information received from the CACR flight simulator.
- A communication system (HLA) to communicate with the CACR flight simulator.
- A Centre Console Instrument Display to show instruments and a second virtual scene (CDTV).
- A tactical display to show a second tactical map for the Mission Commander.
- Forms to send and receive messages.

2.1.9.2 Integrating the ERSTA-like model into the CACR simulation environment

In the CACR CH-146 simulation environment, STAGE software is used generate scenarios. For each entity, such as a ground vehicle or an aircraft, STAGE generates and periodically updates a data structure that contains information about the entity state, including its position, speed, orientation, and other state details. STAGE provides support for plug-ins, such that a user's custom software can access this data.

In the TAMSS SA project, a plug-in was developed that converts specific data into HLA attributes (RPR FOM v1.0) that are then available for all of the federates that subscribe to that federation. The MAK Technologies VR-Link tool is used as a wrapper around the standard HLA API in order to simplify and optimize the use of HLA. The VR-Link tool is used for functionality, such as dead reckoning (to reduce network traffic), smoothing algorithms and coordinate translation. The ERSTA simulation was able to join the federation and subscribe to the attributes that represented the visual entities generated by STAGE. The ERSTA simulation system received periodic attribute updates for each entity. The ERSTA simulation system used the data exported from STAGE to drive the visual representation of the entities through VEGA software. The ERSTA simulation system also received the Ownship position and orientation from STAGE.

2.2 Cognitive Systems Engineering (CSE) Framework

A survey of existing literature on experimental approaches to evaluating Modelling and Simulation (M&S) allowed the development of a Cognitive Systems Engineering (CSE) framework. The CSE framework combines three central constructs in the field of human-machine collaboration: situation awareness, workload, and task-relevant performance. Situation awareness refers to the operator's ability to represent and monitor the ongoing activity, workload refers to the cognitive effort required by the operator, and task-relevant performance refers to the specific aspects of the operators' behaviour that relate to the machine being evaluated. All three aspects of the human-machine system can be evaluated objectively and subjectively (the latter from the perspective of the operator).

The CSE framework was used to guide the investigations in the three TAMSS SA experiments. The overwhelming conclusion is that the CSE framework provides a useful and coherent approach to understanding and measuring the effects of specific technology on the operator-machine system.

2.2.1 Description of the CSE Framework

The CSE framework is based on the application of a human factors approach to understanding cockpit design. In the CSE framework, it is assumed that the strengths and limitations of the human operator must play a role in guiding the development of new aviation systems. Thus, the CSE framework incorporates an understanding of human cognition into a working blueprint for the design of evaluation experiments to support modeling and simulation in acquisition. A more detailed description of the CSE framework may be found in Annex D (see also Annex C).

As shown in Figure 7, the CSE framework includes a theoretical construct, the dynamic mental model, and three empirical (i.e., measurable) constructs; situation awareness, workload, and task-relevant performance. A review of the literature indicated that these three empirical constructs capture a large amount of the variance in the human-machine interface. The proximal goal of the CSE framework is to provide a context within which to develop and interpret the dependent variables that are assessed in an M&S evaluation. The CSE framework is not intended to represent a complete model either of the human operator or of the situation, although further developments of the framework could expand the theoretical and predictive power of the model.

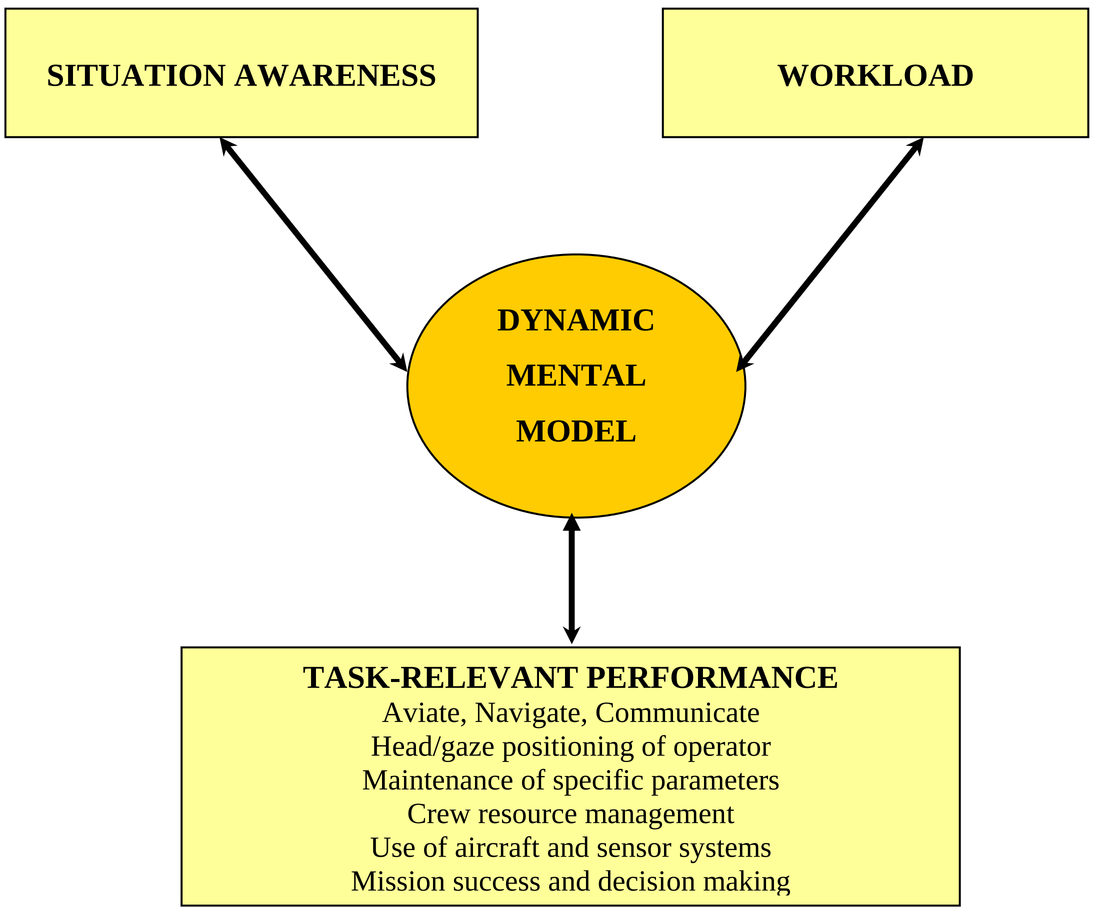

Figure 7 - Cognitive Systems Engineering (CSE) Framework

The central theoretical construct in the CSE framework is the dynamic mental model. It captures the notion that the human operator creates and maintains an internal representation of the ongoing situation. When experimental methods are used to measure performance in an M&S evaluation, all of the measurements are inferences about the operator's dynamic mental model.

The three empirical constructs, situation awareness, workload, and task-relevant performance, are assumed to provide a comprehensive (although not exhaustive) assessment of the dynamic mental model. Situation awareness, defined simply as “knowing what is going on around you” (Endsley, 2000, p. 5) is a construct that was proposed originally to capture why some fighter pilots were more successful (and therefore lived longer) than others (Spick, 1988). As discussed by Endsley (2000), SA is closely tied to knowing how to distinguish important information in the environment from less important information (selective attention), as well as the ability to quickly comprehend the importance of changes to elements in the environment.

The second empirical construct that forms the core of the CSE framework is workload. Workload is a familiar construct in aviation and has been studied more thoroughly than SA. Essentially, workload refers to the fact that humans are limited in their ability to process information and to respond appropriately. Workload has proven to be a very useful construct for understanding changes in operator behaviour under different situational demands and constraints. Technology “improvements” should hypothetically decrease workload, but in practice, a technology that adds information to the pilot’s environment and/or requires the operator to perform additional tasks is more likely to increase workload. Thus, measuring changes in workload as a function of technology change is crucial to understanding how that technology influences the operator.

The third empirical construct in the framework, task-relevant performance, refers to the actions of the pilot (in relation to mission demands) that are potentially affected by the new technology. In essence, a new technology is expected to change some aspect of what the operator knows and that knowledge will be reflected in his or her behaviour. Many other aspects of the operator’s actions or behaviour might not change, however. The task-relevant performance that is relevant to any particular technological change will depend on what that technology was expected to influence. For example, the addition of a new sensor display to the CH-146 Griffon cockpit that assists the aircrew in detecting and identifying targets will likely also result in the aircrew spending time looking and interacting with that display. Concomitantly, the aircrew may spend less time using other sources of information, or may use that information differently. Thus, defining and measuring task-relevant performance is an important aspect of understanding the impact of a new technology on performance in the cockpit.

2.2.2 Applying the CSE framework

In the CSE framework, the three experimental constructs (SA, workload, task-relevant performance) are second-order reflections of the pilot’s dynamic mental model of the situation. It is impossible to directly measure the dynamic mental model (as it is not possible to directly measure “memory” or “thinking”), and thus all measures are behavioural in the sense that the operator or crew must elicit some behaviour or perform some action that is then assessed. For example, a subjective assessment of SA requires that the pilot make a judgment or provide an evaluation. Head position could be used as an index of where the pilot is attending. Flight path could be used as an index of the pilot's adherence to the boundaries of a safe air corridor.

A central tenet of the CSE framework is that human-machine interactions are often too complex for a single concept to provide sufficient information to evaluate the impact of an interface on the operator's overall behaviour. By distinguishing among SA, workload, and performance and the underlying mental representation (the dynamic mental model), researchers can more clearly operationalize the concepts for empirical purposes. Indeed, due to the complexity and multi-dimensional nature of the dynamic mental model, any single construct or any single measure of a construct is unlikely to capture sufficient information about the impact of a new technology. In addition, under some conditions a high correlation between the measures of the empirical constructs should not be expected. For example, good SA does not always lead to good performance and high workload does not always predict poor performance. Nevertheless, these constructs are related and in many situations, good SA will predict good performance. Accordingly, it is recommended that a CSE evaluation should include at least one, and preferably multiple measures of each of situation awareness, workload, and task-relevant performance. Use of multiple measures will allow for a richer and more accurate index of how new technologies affect the human-machine interaction.

2.3 TAMSS SA Experiment One

2.3.1 SA, Workload, and Performance in Simulated Flight: HUD vs. HDD

Experiment 1 was designed to (a) provide a preliminary evaluation of the Cognitive System Engineering (CSE) framework and (b) develop and test the technical and experimental capabilities of the Carleton University simulator facility. In this experiment, trained CF pilots flew a series of simplified recce-type missions while wearing a Helmet Mounted Display (HMD). Two conditions were compared: Heads-Up Display (HUD) versus Heads-Down Display (HDD). In the HUD condition, the HMD was equipped with HUD symbology showing primary flight, power, and navigation information. The HUD symbology was derived from the CH-146 LATEF II HUD. In the HDD condition, the HMD was not equipped with HUD symbology. Instead, pilots were required to look under the HMD to acquire the requisite information from the head-down instrument panel. The HDD condition is similar to that experienced by CH-146 pilots using Night Vision Goggles (NVGs): when the NVGs are not equipped with a HUD, the pilots must look under the goggles to read information from the instrument panel.

Pilots flew a series of the simplified recce-type missions. On each mission, they initially took off from a base, located centrally in the area of interest. They were then directed (using radio comms) to find a series of waypoints (towers placed in the terrain) by an experimenter who gave them heading values. Pilots were given specific altitude and airspeed parameters that were to be maintained throughout the missions. In addition, pilots were instructed to provide reports (sitreps) of any and all activity (in the air or on the ground). Accordingly, each scenario was populated with a variety of objects. The objects included (a) two moving formations of three armored ground cars, (b) three stationary pieces of artillery (Howitzer guns), (c) four grounded CH149 Cormorant helicopters, (d) one wrecked CH149, (e) two CH149s flying in small loop formations, (f) two hovering CH-146 Griffon helicopters, (g) one formation of four CF18s flying in a wide formation across a large portion of the terrain, and (h) one C130 Hercules fixed-wing transport aircraft flying a slow, elongated loop pattern that cut across the whole width of the database terrain, roughly five kilometres from the southern edge of the terrain. All objects were placed so that they were on, or intersected, the paths that pilots flew in their missions. Hence, most objects were close to the edges or on the diagonals of the square formed by the database, and were either on the ground or at a fairly low altitude (below 300 feet). The CF18s and the C130 flew relatively slow and wide trajectories that intersected the pre-planned mission routes at fairly regular intervals. All entities were scaled to their normal size relative to the database. The objects varied in visibility, but all were visible for a minimum of 2 to 3 seconds. A more detailed description of Experiment One may be found in Annex E.

2.3.2 CSE Measures

A central premise in the CSE framework that that converging measures should be obtained in order to gain an overall perspective that does not rely solely on a single construct or single method of measurement. Accordingly, in Experiment 1 all three dimensions of behaviour outlined in the CSE framework were sampled: situation awareness, workload, and task-relevant performance. Subjective and objective measures of each dimension were developed as follows.

1. *Situation Awareness.* The objective index of situation awareness was the percentage of objects that pilots missed during each mission. After each mission, pilots also subjectively rated their perceived awareness overall and for specific flight parameters (speed, altitude, and heading), and for activity in the environment.

2. *Workload.* Workload was assessed through the presentation of auditory and visual probes during a subset of the missions. Both the latency to the probes and the percentage of probes missed was measured. Subjective ratings of workload, globally and during specific legs of the recce, were also collected.

3. *Task-relevant Performance*. Although performance was measured exhaustively, the primary focus in this experiment was on deviations from the specified airspeed and altitude parameters. In addition, subjective ratings of performance and of task difficulty were collected after each mission.

2.3.3 Findings

The results from Experiment 1 focused on the impact of the HUD versus HDD on pilot situation awareness, workload and task-relevant behaviour.

2.3.3.1 Situation awareness

The results from Experiment 1 showed that the pilots' objective situation awareness was worse in the HUD than in the HDD condition. Pilots missed more objects in the HUD condition than in the HDD condition, with the airborne objects (i.e., F18s, Hercules, and other helicopters) showing the greater effect. These SA differences between the HUD vs. HDD conditions do not appear to be due to relative duration or relative visibility of the various objects, as there was a considerable range for both airborne and ground-based objects.

The objective and subjective measures of SA showed moderate convergence in this experiment. Pilots rated their overall SA as somewhat worse in the HUD than in the HDD condition, in accord with their actual performance on the objective SA (detection) task. However, the pilots did not subjectively perceive that their performance on detecting airborne objects as being worse with the HUD, suggesting that their subjective access to specific aspects of their SA was low.

2.3.3.2 Workload

Pilots missed more of the auditory and visual probes (i.e., tones and light flashes) when they were using HUD symbology than when they were using the instruments. Similarly, their response times to the probes were also slower in the HUD than in the HDD condition. These objective measures show that pilot workload higher in the HUD than in the HDD condition. In contrast to the objective measure of workload, pilots subjectively rated their workload as similar in the HUD versus the HDD condition.

2.3.3.3 Task-relevant performance/behaviour

Task-relevant performance (i.e., maintaining specified airspeed and altitude) did not vary across conditions. Pilots were able to maintain the specified flight parameters within reasonable boundaries in both HUD and HDD conditions. Interestingly, , pilots rated their performance as worse with the HUD than with the instruments. They indicated that their performance on maintaining airspeed and altitude (as well as cross-checking instruments and using information from the external scene) was worse with the HUD than with the HDD. This suggests that pilots were aware that they were less able to fulfill all the demands of the missions with the HUD, but that a direct question about performance was more sensitive to these differences than questions about SA or workload. One possible explanation of these results is that pilots are more able to evaluate their performance (because they have direct experience of it) than to evaluate workload or SA, which are hypothetical constructs, that may have different subjective meanings to different individuals.

2.3.4 Impact

Experiment 1 supported the validity of the CSE framework for use in M&S assessments of technology. In particular, this research showed that converging objective and subjective measures of situation awareness, workload and performance should be used in order to obtain an overall perspective that does not rely solely on a single construct or single method of measurement.

The importance of obtaining converging measures was highlighted in the SA and workload results. To wit, while there was moderate convergence between the objective and subjective measures of SA, the pilots did not subjectively perceive that their SA for airborne objects was worse in the HUD versus the HDD condition. A similar dissociation also occurred for the subjective versus objective measures of workload: whereas the objective measures showed that workload was higher in the HUD than in the HDD condition, pilots subjectively rated their workload as similar across these two conditions.

Further support for the CSE converging measure approach was found in a separate questionnaire focused on the use of the HUD. In this questionnaire, all of the pilots subjectively rated the HUD as much better than the HDD condition for increasing “eyes out” time. Thus, pilots perceived an advantage for the HUD in the sense that they felt they were more likely to be looking out of the cockpit. However, as is evident from the objective SA data, the HUD actually diminished the pilots’ ability to notice objects in the environment. Interestingly, although the pilots reported some specific difficulties with the HUD symbology, they did not translate this into an overall more negative evaluation.

In sum, the combination of measures used in this study showed that the objective and subjective indices of these constructs were not always perfectly aligned. It is clear that the combination of the subjective and objective measures is important for understanding the effects of the unfamiliar HUD symbology on situation awareness, workload, and performance.

The Experiment 1 finding that the pilots failed to detect more ground and airborne objects when using a HUD is consistent with other simulation-based research in the literature. Although HUDs have been shown to be effective in specific tasks such as controlling flight path and altitude (e.g., see Fadden, Ververs, & Wickens, 2001; Martin-Emerson & Wickens, 1997; Wickens & Long, 1995), there are a number of simulator-based studies suggesting that pilots may focus or 'cognitively tunnel' their attention on HUD symbology (Brickner, 1989; Fischer, Haines, & Price, 1980; Foyle, Stanford, & McCann, 1991, Wickens & Long, 1995). Cognitive tunneling is believed to cause pilots to miss potentially critical events in the external scene. For example, Fisher et al. found that in a simulated landing task, pilots were less likely to detect a runway incursion (e.g., a vehicle driven onto a runway) when they were using a HUD than when they were using a conventional head-down display. In the present research, the object detection task was more naturalistic than those used in previous simulator-based studies of cognitive tunneling. Thus, the present research findings are of particular importance to the cognitive tunnelling literature as well as to programs aimed toward the future development and implementation of HUDs.

2.4 TAMSS SA Experiment Two

2.4.1 The Impact of an ERSTA-Like System on the CH-146 Mission Commander

Experiment 2 involved three major activities. The first activity was to integrate the DND ERSTA-like model with the CH-146 simulator facility at the Carleton University CACR. This activity included:

1. Modifying the extant ERSTA-like model to reflect the core mapping and sensor capabilities of the ERSTA system that is anticipated for the CH-146 Griffon,

2. Designing and implementing moving map and sensor display interfaces for the cockpit,

3. Making the ERSTA model compliant with High-Level Architecture (HLA) specifications, and

4. Linking the HLA-compliant ERSTA model with the CACR CH-146 simulator.

The second major activity was to further develop the data collection capabilities of the simulation environment. The simulation environment was significantly more complex given the requirement to integrate the ERSTA simulation with the flight simulator using HLA.

The third major activity in Experiment 2 was to conduct a study to exercise the Cognitive Systems Engineering (CSE) framework that has been proposed by the Carleton University CACR. In Experiment 2 this was accomplished by evaluating the impact of the prototyped ERSTA-like moving map and sensor capability on CH-146 Griffon aircrew. The particular focus of the experiment was on how the ERSTA-like capability affects the situation awareness, workload and performance of the CH-146 Mission Commander (MC).

In this experiment, aircrew consisting of a Flying Pilot (FP) and a Mission Commander (MC) completed a series of zone recce missions. An example of a mission scenario is given in Annex F: further details regarding the missions can be accessed in the TAMSS SA report on Experiment 2.

Of primary interest was how an ERSTA-like tactical moving map and sensor capability affected the situation awareness, workload and performance of the CH-146 MC while completing these missions. Three conditions were compared in the experiment:

1. *Paper Map (P-Map).* This is a baseline condition that reflects the current situation in the CH-146 where aircrew (i.e., the MC) navigate using a hand-held paper map and detect and identify targets without aid of a sensor.

2. *Moving Map (M-Map).* In this condition, the MC was provided with a digital moving map (positioned on the lap). A paper map was also provided for use at the discretion of the MC. As in the paper map condition, the aircrew were required to detect and identify targets without aid of a sensor.

3. *Moving Map plus Sensor (M-Map/Sensor).* In this condition, the digital moving map (and the paper map) and the ERSTA sensor capability were provided. The ERSTA sensor (camera) image was displayed on the front centre console, i.e., where the current CH-146 FLIR image is normally located. In this condition, aircrew were able to use the sensor image to support target detection and identification.

A more detailed description of Experiment Two may be found in Annex F.

2.4.2 CSE Measures

Experiment 2 was designed to sample all three dimensions of behaviour outlined in the CSE framework: situation awareness, workload and task-relevant performance. Subjective and objective measures of situation awareness and task-relevant performance were obtained. For workload, only subjective measures were obtained.

1. *Situation Awareness.* Situation awareness was objectively measured as the percentage of relevant objects that aircrew missed during each mission. Subjective ratings of SA were obtained in questionnaires that were administered following each mission.

2. *Workload.* Workload was assessed subjectively using questionnaires based on a modified NASA TLX. Subjective ratings for global workload were obtained as were ratings for specific segments (e.g., ingress, recce-zone, egress) in the missions. Objective measures of workload were not directly obtained.

3. *Task-relevant Performance.* Three objective measures of task-relevant performance were planned. (a) The impact of the digital moving-map capability on navigation, the positioning of the ownship relative to the defined flight ingress corridors leading to the RP was measured. (a) The impact of the ERSTA-like camera sensor was objectively defined as the distance at which the aircrew detected and identified targets. (c) It was hypothesized that the ERSTA-like digital moving map and sensor would affect how much time the MC spent looking down and inside the cockpit. This was objectively assessed by recording the head positioning of the MC throughout the missions. Subjective ratings of performance were collected after each mission.

2.4.3 Findings

A major challenge in Experiment 2 was to develop and integrate the ERSTA-like simulation model into the CACR CH-146 simulation environment using HLA. This integration was successful insofar as the ERSTA-like simulation was functional throughout the experiment. However, the increased complexity of integrating ERSTA-like system into the distributed simulation environment raised a number of technical challenges. In particular, online data collection was compromised in Experiment 2. These technical challenges were identified and addressed in Experiment 3.

The primary focus in Experiment 2 was to evaluate how the ERSTA-like tactical moving map and sensor capability affected the situation awareness, workload and performance of the CH-146 MC.

2.4.3.1 Situation awareness

Providing the ERSTA moving map display and the sensor display (M-Map/Sensor condition) resulted in higher SA for the CH-146 MC. Objectively, the MCs' situation awareness for relevant airborne and ground vehicles was very high in that virtually all of these objects were in detected and reported in an appropriate and timely fashion. MCs' subjective ratings of their SA for tactical information relevant to the mission were generally higher in the M-Map/Sensor condition than in the P-Map and M-Map conditions. In addition, the MCs rated their SA as higher in the M-Map/Sensor condition for tracking the unfolding of a mission and for anticipating future events. Ratings of spatial/navigational awareness in the MC position were also highest in the M-Map/Sensor condition. Importantly, these ratings showed a clear advantage of the M-Map/Sensor condition for locating ownship relative to the objective (e.g., bridge) and relative to enemy activity as well as for awareness of the general layout of the navigated area.

2.4.3.2 Workload

Objective measures of workload were not obtained in Experiment 2. Subjective ratings of workload did not differ dramatically across the three conditions, but on average providing a moving map lowered the MC's perceived workload. As would be expected, MCs rated workload as being highest for activity in the recce zone as compared to the ingress and egress activities. Written comments from participants confirmed that workload for the MC was high in the recce zone "due to the number of agencies that needed to be contacted on different frequencies". It was also noted that high workload for the MC in the recce zone was mainly associated with trying to maintain SA of the ownship location. It was noted that the digital moving map reduces workload related to navigation thereby freeing more other tasks (comms, search etc.).

2.4.3.3 Task-relevant performance/behaviour

Head position data of the MCs was collected throughout each mission. However, technical difficulties were such that stable and complete data was only obtained for one participant. This participant's data showed that percent head-up time was greater in the M-Map (49%) and M-Map/Sensor (48%) conditions than in the P-Map (33%) condition. This finding suggests that the ERSTA capability had the positive benefit of allowing MCs to spend more time looking outside the cockpit. Head-up time should impact on flight safety and enhance the contribution of the

MC in detecting and responding to information external to the cockpit. Subjective ratings of performance for various tasks in the MC position increased from an average of "adequate" in the P-Map condition to "good" in the M-Map and the M-Map/Sensor conditions. As expected, performance ratings in the M-Map and M-Map/Sensor conditions were noticeably higher than the P-Map condition for the navigation tasks such as finding waypoints, reading the map and using the map to navigate. The ERSTA capabilities were also rated as enhancing the MC's positioning of the aircraft in the recce zone.

2.4.3.4 Impact

The results of Experiment 2 show that the expert participants perceived an advantage for the ERSTA-like digital moving-map and sensor capabilities in their mission activity. Participants agreed that the moving map and sensor enhanced the MC's performance and SA while generally lowering task difficulty and workload. There was also some indication of these benefits being transferred to the FP, particularly in terms of the aircrew's ability to position the aircraft and to maintain tactical flight. In addition, although limited to one participant, the head tracking data showed that the MC was able to spend more time looking up and out of the cockpit when provided with the digital moving map and sensor image.

Experiment 2 provided a solid foundation for developing Experiment 3 of the TAMSS SA project. Of importance is that (a) the ERSTA-like system was effectively modeled and integrated into the simulator environment using HLA protocol, (b) the missions scenarios that were developed and implemented represented realistic tactical missions, and (c) the questionnaire battery developed for obtaining subjective measures proved to be sensitive and appropriate for indexing and differentiating SA, workload and performance across the experimental conditions.

2.5 TAMSS SA Experiment Three

2.5.1 Impact of a Mission Specialist on the CH-146 Mission Commander

The primary goal of Experiment 3 of the TAMSS SA project was to exercise and evaluate the Cognitive System Engineering (CSE) framework for assessing the impact of novel technology on CH-146 aircrew. In this experiment, trained CH-146 aircrew completed a series of recce missions. On half of the missions the crew included a Flying Pilot (FP), Mission

Commander (MC), and a Mission Specialist (MS). On the other half of the missions, the MS was not included. Of interest was how the presence versus absence of the MS affected the situation awareness, workload and performance of the CH-146 MC while completing the recce missions.

There were three major activities in Experiment 3. The first activity was to extend the ERSTA-like model and control capabilities and to further integrate this with the Carleton University CH-146 simulator environment. The second major activity was to provide a more stable HLA-based distributed simulation environment, including refinements to the data collection capabilities of the simulator environment. The third major activity was to conduct a study to further test the CSE framework by examining the situation awareness, workload and performance of the CH-146 Mission Commander (MC) under conditions where a Mission Specialist (MS) was present versus a conditions were a Mission Specialist was not present. A more detailed description of Experiment Three may be found in Annex G.

2.5.2 Extend ERSTA-Like Model

The first major activity was to extend the functionality and control capabilities of the ERSTA-like simulation beyond those that were initially modeled in Experiment 2 of the TAMSS SA project and to enhance the integration of this model with the Carleton University CH-146 simulation environment. A summary of the ERSTA-like system, hardware and software architecture is presented in Annex A.

Extending the ERSTA-like system included modifying the model that was used in Experiment 2 to provide:

1. Additional functionality to the digital moving map display, including a military grid overlay for the digital map, touch accessible grid read-out capabilities from the digital moving map, and user options for using North-up versus heading-up orientation.

2. Control capability of the sensor image for the MC.

2.5.3 Enhance stability of simulation environment

The second major activity in Experiment 3 was to improve the stability and utility of the simulation environment. The enhancements to the simulation environment included:

1. Improving the fundamental stability and performance of the ERSTA-like model.

2. Stabilizing the flight simulator through programming upgrades and modification of the core simulation and HLA software.

3. Further integration of the ERTSA-like model and the flight simulator.

4. Improvements to the data collection capabilities within the distributed simulation environment.

2.5.4 Conduct Experiment

The third major activity was to design, conduct and analyze the experiment. The primary goal of Experiment 3 was to determine whether the CSE framework could be used to measure the impact of the ERSTA-like system on the CH-146 aircrew, and in particular, on the SA, workload and performance of the CH-146 MC. To do this the following two conditions were compared:

1. *Mission Specialist Present.* In this condition, the crew included a Mission Commander (MC), Flying Pilot (FP), and a Mission Specialist (MS). The MS assumed primary operation of the ERSTA-like system, in and particular, the sensor. The MC was able to view and interact with the digital moving map and if desired, take control of the sensor.

2. *No Mission Specialist Present.* In this condition, the crew consisted of the MC and FP. A MS was not present. In this condition, the MC assumed responsibility for operating the ERSTA-like system.

The execution of Experiment 3 was enabled by the major engineering activities described above, as well as by the following activities:

1. Input from Subject Matter Experts (SME) regarding the functionality and use of the ERSTA-like system as well as how mission specialists could be integrated into the CH-146 aircrew.

2. Modification of the tactical scenarios that were used in Experiment 2 of the TAMSS SA project in order to provide Fire Mission Support (FMS) capabilities in the scenarios.

3. Development of tactical knowledge and the expertise to allow for dynamic control of elements by the experimenters during the missions, including the escalation of enemy activity.

4. Modifications of the questionnaire battery from Experiment 2 that were used for obtaining subjective ratings of performance, situation awareness, and workload.

2.5.5 CSE Measures

In Experiments 1 and 2 of the TAMSS SA project, it was demonstrated that expert’s self ratings of their SA, workload and performance can provide a reasonable index concerning the impact of a new cockpit technology (i.e., HUD). In addition, Experiment 1 demonstrated that SA could be objectively assessed by measuring a pilot's ability to detect and report airborne (e.g., other aircraft) and ground entities (e.g., tanks, downed aircraft) while performing a mission. An important finding from Experiment 1 was that this objective measure revealed significant differences in SA even under conditions where the pilots' subjective ratings of SA were not different.

In the present experiment, all three dimensions of behaviour outlined in the CSE framework were measured subjectively: SA, workload, and performance. In addition, a focus was placed on obtaining an objective measure of workload as well as objective measures of performance/behaviour.

1. *Situation Awareness.* Situation awareness was measured subjectively in this experiment by having the participants complete Likert-scale ratings of SA after each mission. Objective measures of SA were not obtained.

2. *Workload.* Following each mission, the FP and MC completed separate Likert-scale questionnaires of workload as well as workload ratings based on a modified NASA TLX. Subjective ratings for global workload were obtained as were ratings for specific segments (e.g., ingress, recce-zone, egress) in the missions. Workload was objectively assessed using a visual detection task whereby the MC was required to indicate when they detected a visual target (a briefly displayed green circle) on the front screen. The targets subtended approximately 2 deg of visual angle and were presented every 15 sec (+/- 3 sec randomly determined) throughout the workload missions.

3. *Performance/Behaviour.* Following each mission, the participants completed subjective ratings of their performance in the mission. Two objectives measures were taken. One objective measure was the head-positioning of the MC. It was hypothesized that when a MS was included in the crew, the MS would be given primary responsibility for operating the ERSTA-like sensor. For missions where the crew did not include a MS, the MC was required to control the sensor image. It was predicted, therefore, that MCs would spend less time with their heads down and inside the cockpit when a MS was present as compared to when a MS was not present. The second objective measure was the amount of time the sensor was used throughout a mission. It was predicted that the crew's use of the sensor would be greater when a MS was present. When a MS was not present, the MC would have limited time available for controlling the sensor.

2.5.6 Findings

As in Experiments 1 and 2, the primary focus of Experiment 3 was on the MC. As summarized below, the presence of a MS had a significant impact on the SA, workload and performance of the MC. There were, however, indications that the presence of the MS also had a positive impact on the flying pilot. In particular, flying pilots found that the ERSTA-related information was more useful when the MS was operating the ERSTA system than then the MC was operating the ERSTA system. Related to this was a trend for higher subjective ratings of SA related to tactical awareness, and in particular for the flying pilots' (rated) ability to anticipate future developments. The remaining discussion is centered on the MC.

2.5.6.1 Situation Awareness

Subjective ratings showed that the MCs' self-rated SA ranged from "moderate to good", with SA was rated as being significantly higher in the MS-present than in the No-MS condition. This was true for the MCs' ratings of tactical awareness, spatial awareness, and crew awareness.

2.5.6.2 Workload

Subjective ratings for the MC showed that workload was rated as lowest during ingress and egress and highest during activity associated with observing targets and activity in the recce zone. During ingress, egress and general transit segments of the mission, there were no significant differences in the MCs' rated workload between the No-MS versus the MS-Present conditions. However, while in the recce zone and also when observing targets (e.g., a choke point or enemy activity) rated workload was generally higher in the No-MS than the MS-present condition.

The MCs' workload was objectively assessed using a visual detection task whereby the MC was required to indicate when they detected a visual target (a briefly displayed green circle) on the front screen. The MC responses to the visual targets were divided into transit versus observation/contact segments. The transit segment category included the MC responses to the visual targets when the crew was engaged in the initial ingress, transit from the RP to the first observation point, moving from one observation point to another observation point, and egress. The observation/contact category refers to MC responses to the visual targets when the crew was observing a target/objective, submitting a contact report, or performing a FSM. The results showed that MCs detected most (average of 82%) of the visual targets while in transit. Performance while in transit did not differ between the MS-Present versus the No-MS conditions. In contrast, the MCs detected fewer visual targets (average of 56%) while in an observation/contact phase. Moreover, significantly fewer visual targets were detected in the No-MS than in the MS-Present condition. This shows that the MC had less visual attention to allocate to the target detection task in the No-MS condition than in the MS-Present condition.

2.5.6.3 Task-relevant performance/behaviour

The MCs' subjective ratings of performance varied from "slightly less than adequate" to "good", depending on the task. On all but two tasks (using comms and positioning the sensor) the MCs rated their performance as being better when a MS was present as compared to when no MS was present.

One objective measure of performance/behaviour was the head-positioning of the MCs. Head position data for the MC was collected throughout each mission. Overall, percent head-up time for the MC was significantly greater (better) when a MS was present (37% head-up time) as compared to when a MS was not present (20% head-up time). Head-up time should impact on flight safety and performance: enhanced head-up time should facilitate the MC's ability to detect and respond to information external to the cockpit. A close examination of the data showed that when there was no MS present, the MC spent more time looking at the ERSTA sensor image and the ERSTA digital moving map. This extra time on the sensor was likely due to the additional requirement on the MC to operate the sensor when there was no MS. Operating the sensor requires frequent use of the digital map orienting and moving the sensor (touch-click operation). These findings concurs with the subjective ratings of difficulty where MCs indicated that "use of the sensor", "positioning the sensor" and "getting information from the sensor" was quite difficult in the No-MS condition.

A second objective measure of performance/behaviour was sensor usage. The average percent time that the sensor was used was computed relative to the overall mission time. When a MS was present, the sensor was moved by the MS for an average of 40% of the overall mission time. When a MS was present, the sensor was controlled by the MC only 1.7% of the time: thus, the MS had the primary responsibility for moving the sensor. When there was no MS present, the sensor was used by the MC for an average of 27% of the overall mission time. Thus, when there was no MS, the sensor was used less then half of the time compared to a situation where a MS was included as part of the aircrew.

2.5.7 Impact

The primary goal of Experiment 3 was to extend the evaluation of the Cognitive System Engineering (CSE) framework for evaluating the impact of novel technology on aircrew. To do this, the impact of an ERSTA-like system was assessed with a particular focus on how ERSTA affects the situation awareness, workload and performance/behaviour of the MC. Two conditions were examined: Mission Specialist Present versus No Mission Specialist.

The results of Experiment 3 provide a clear picture of how measuring the three CSE constructs (situation awareness, workload, and task-relevant performance) can provide a broad but integrated assessment of how novel technology can impact aircrew. In Experiment 3, the use of the ERSTA-like system benefited from the addition of a mission specialist to the CH-146 aircrew. In particular, when a MS was present to operate the ERSTA system, the MC, freed from the increased demands of operating the sensor, had more mental attention to put towards the primary demands of the MC role.

Experiment 3 was also technically progressive. The ERTA-like model was successfully extended to provide an enhanced level of functionality thereby enabling the aircrew to use the digital moving map and the sensor capabilities in a realistic and appropriate manner. The Carleton University HLA-based distributed simulation environment was robust and stable. The data collection utility was stable and accurate throughout the experiment and the HLA-based distributed simulation which the CACR used to connect the model of the ERSTA system to the CACR CH146 flight simulator ran flawlessly for a minimum of eight-to-ten hours per day across twelve days of testing.

2.6 Summary of TAMSS SA Project Activities

Two major activities were completed in the TAMSS SA project. The first major activity was to establish a research-enabling CH-146 simulation environment at the Carleton University CACR. The second major activity was to conduct three graduate-level research studies on Situation Awareness (SA). These major activities resulted in the following deliverables:

1. The development of a CH146 Griffon simulation capability at the Carleton University Centre for Applied Cognitive Research,

2. The development of a Cognitive Systems Engineering (CSE) framework to guide the simulation-based evaluation process,

3. Three experiments that both assessed the engineering system and the theoretical framework, and

4. This final document, which explains and summarizes the process.

The Carleton University CACR CH-146 simulation environment was developed across the extent of the TAMSS SA project. This cost effective and malleable environment was proven to be an effective platform for prototyping and exercising systems and for measuring the impact of new technologies in a dynamic simulation environment.

The CSE framework was used to guide simulation-based evaluations in the three TAMSS SA studies: this framework provides an effective structure for simulation-based evaluations human-machine systems. For each of the three TAMSS SA studies, trained CH-146 aircrews completed simulated reconnaissance missions. In Experiment 1, CH-146 pilots showed reduced situation awareness and increased workload when they were using a heads-up display. In Experiment 2, ERSTA-like sensor capabilities, combined with a digital moving map, allowed CH-146 mission commander to gain enhanced situation awareness and at times reduced workload. In Experiment 3, it was shown that the presence of a mission specialist to operate an ERSTA-like sensor system allowed the CH-146 mission commander to have increased heads-up time, substantially decreased workload, and enhanced situation awareness.

The TAMSS SA project is also important in demonstrating that the fidelity obtained with a relatively inexpensive simulation based on PC platforms is sufficient for exercising and measuring the impact of technology in an operator-machine system. In addition, the TAMSS SA project showed how High-Level Architecture (HLA) can be used to connect distributed models in a manner that is achievable in simulation-based evaluation programs. In summary, the TAMSS SA project provides a guide for the implementation of simulation-based acquisition in a cost effective, malleable platform.

3. CSE Framework and Acquisition Programs

3.1 Role of the CSE Framework in Acquisition Programs

As illustrated in Figure 8, acquisition programs follow a sequence of steps ranging from Concept Development and Exploration (CDE) through to Options Analysis, Definition and Implementation. For each of these steps in the acquisition process, risk can be reduced through the use of CSE-based modelling and simulation for design, rapid prototyping and simulation-based evaluation activities.

3.1.1 An Iterative Modelling and Simulation Process

In Figure 8, the top-level callout shows three stages involved in modelling and simulation: design, rapid prototyping and SBE. The left-to-right sequence (as indicated by the horizontal arrows) illustrates that modelling and simulation normally starts with a design phase, followed by rapid prototyping and SBE. An important feature of modelling and simulation activities, however, is that iterative feedback to earlier activities is enabled. This iterative feedback is shown as the vertical arrows in the top-level callout of Figure 8.

The iterative, feedback-enabled approach is required for modelling and simulation to be maximally effective for acquisition. For example, the development of a rapid prototype and/or the use of simulation-based evaluation may reveal system limitations or raise alternative solutions that were not identified in the initial design stage. Similarly, while activity in the SBE stage may validate the rapid prototypes, SBE activity can also reveal the need for changes in the prototypes.

At a theoretical level, the feedback between the stages can be thought as a cascading error-correcting mechanism, similar in principle to that used in Perceptual Control Theory (PCT: Hendy et al., 2002). On this view, feedback continues until the difference between outputs from the stages reaches an acceptable criterion. More generally, this process can be viewed as satisfying a set of hierarchically defined set of goals. Top-level goals will be consistent across the stage of the acquisition process. However, specific goals will be driven by the concept development, option analysis, definition and implementation stages.

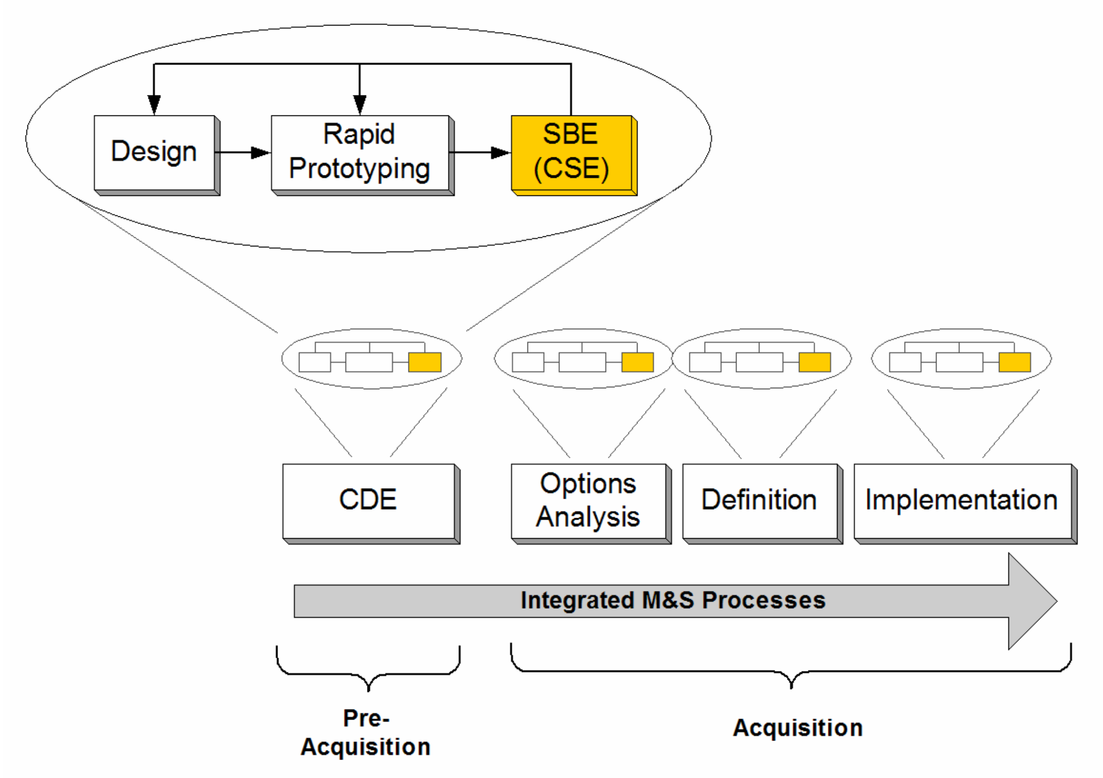

Figure 8 - Integration of Modelling and Simulation into the Acquisition Process

3.1.2 CSE-Based Modelling and Simulation

The CSE framework that was developed in the TAMSS SA project provides a structure for modelling and simulation activities in each of design, rapid prototyping and Simulation-Based Evaluation (SBE). For design and rapid prototyping, the constructs in the CSE framework orient activity toward consideration of how the human-machine system will potentially affect operator SA, workload and task-relevant performance. The CSE framework, however, is particularly germane to SBE: the CSE framework provides both a conceptual structure and strong methodological guidance for SBE activities.

The use of a CSE-based modelling and simulation approach for acquisition programs is based on three fundamental premises:

1. *Premise 1: Human-machine systems are constrained by limitations in human abilities.* Whereas technologies can be further developed and modified, humans remain inherently limited in their ability to attend, process information, time-share tasks, comprehend events, make decisions and elicit correct actions. To some extent, training can counter these limitations and/or allow these limitations to be managed. However, fundamental limitations in human abilities can not be eliminated. It is important therefore, to fully consider human abilities and limitations from

the early stages of concept development through to system implementation. For acquisition programs, the CSE framework provides a manageable and comprehensive approach by grouping the examination of human abilities into three constructs: SA, workload and task-relevant behaviour.

2. *Premise 2: Systematic assessment and measurement is required.* In accord with thte CSE framework, assessing the capabilities of a human-machine system is achieved through (a) the systematic manipulation of relevant variables that exercise the human-machine system and (b) the measurement of operator SA, workload and performance. An advantage of modelling and simulation is that it can be used to represent the intended use, dynamics and functionality of the human-machine system in an interactive and realistic environment.

3. *Premise 3: CSE-based modelling and simulation lowers acquisition cost and enhances likelihood of success.* Information derived from CSE-based modelling and simulation can both validate and expedite activities in the acquisition process, ranging from concept development through to implementation. Further, CSE-based modelling and simulation involves end-users resulting in better informed and more confident procurement. This empowers procurement personnel through informed decision making which in turn allows the acquisition process to proceed in a timely and cost-effective manner while increasing the likelihood of successfully acquiring the optimal system.

3.1.2.1 CSE-based modelling and simulation: Simulation fidelity issues

Obtaining valid and meaningful measures of the operators' SA, workload and performance may require special consideration regarding the fidelity of the synthetic environment. In SBE one important criterion concerning fidelity is whether the participants "accept" the simulation environment as a meaningful representation. This criterion essentially reduces to whether the operators become effectively immersed in the synthetic environment to the extent that they (a) operate the systems in an appropriate fashion and (b) perform the tasks in a manner analogous to how they would operate the systems in a real platform. Besides subjective experience, there are a number of components to a simulation environment that for which fidelity must be considered. As an example, in the TAMSS SA project fidelity considerations for the CACR CH-146 simulation environment included the following:

1. *Visual system.* The resolution and update rate of the visual must be sufficient to enable operators to view and use the Out-The-Window (OTW) scene effectively. For example, in the

TAMSS SA project, the fidelity of the visuals were sufficient to enable pilots to use the OTW scene for low-level and NOE tactical flight.

2. *Flight controls.* The cyclic and collective controls in the TAMSS CH-146 simulator are of low fidelity. These controls, however, were tuned to approximate the response of the CH-146 and were sampled at a rate that allowed for predictable and timely responses. These controls are not of high enough fidelity to allow for pilot flight (aviate) training, but were sufficient to allow pilots to fly the simulated CH-146 at tactical levels (including hover), usually with less than 5 minutes of practice.

3. *Instrumentation.* In many simulation environments, glass panel (often LCD) instrument displays are used. These displays visually correspond to the instruments in the real aircraft, but do not provide tactile feedback. In many cases a glass panel representation is suitable. In other cases, tactile feedback is an important component of the operator's experience. For example, experienced CH-146 aircrews rely upon tactile feedback when entering information into the CDU (button shapes, perceptible clicks). For this reason, the TAMSS CH-146 system includes CDU bezels and Communication Selection Control (CSC) panels that are very similar to those in the CH-146 helicopter and that provide high tactile fidelity.

4. *Scenario generation.* To measure SA, workload and performance in a manner that provides face and construct validity, simulation-based evaluations may require participants to perform in scenarios that are as realistic as possible. Thus, scenario generation must allow for the use of accurate models (e.g., models of vehicles, weapons) and when feasible, provide a dynamic flow of events. Depending on the system that is under evaluation, the scenario generation utility may require the ability to vary environment factors such as wind and visibility. The fidelity of the environmental models will depend on the specific systems and questions that are being examined in the simulation-based evaluation.

5. *Data collection.* The fidelity of data collection in a simulation environment is important and complex. Issues surrounding data collection are more complex when a distributed simulation environment is used. Some variables must be sampled at high rates (e.g., 60 Hz or better), whereas others can be sampled at lower rates. For evaluations using operators' response latencies as a measure, data collection

may need to be accurate to 1 – 5 milliseconds. The CSE framework can be used to select measures and to specify the level of resolution that is required for these measures to be valid and useful. This will directly affect the design and system architecture of the simulation environment that will be used for the evaluation. A detailed discussion of data collection in the TAMSS SA project is presented in Section 2.1.8.

A useful criterion concerning data collection fidelity is whether variations in the key factors examined in the simulation-based evaluation resulted in detectable differences in the CSE measure(s). In general, if the CSE measure(s) shows change that correspond to variation in the manipulated variables, then it is concluded the manipulated variables, the measures, and the simulation environment are of sufficient fidelity. However, firm conclusions are difficult to make when the manipulated variables do not affect the measured variables: this is referred to as a "null effect". Null effects may occur because the manipulated variable simply does not have an impact on the operator's SA, workload or performance. Alternatively, however, null effects may reflect (a) weak (low fidelity) or possibly irrelevant manipulations, (b) an insensitive (low fidelity) or irrelevant measured variable, or (c) an inadequate (low fidelity) simulation environment. In sum, it is generally very difficult to interpret null effects. An evaluation that produces only null effects will require further investigation into the fidelity of the manipulated variables, the measured variables, and the simulation environment.

3.1.3 Reduced Costs and Time-Lines Using Modelling and Simulation

A fundamental premise underlying the use of modelling and simulation in the acquisition process is that there must be an allowance for iterative cycles among the stages as shown in Figure 8 - Integration of Modelling and Simulation into the Acquisition Process. Iteration does <u>not</u> imply increase cost or extended timelines. Time-lines associated with rapid prototyping and simulation-based acquisitions are relatively short. Importantly, the information derived from these activities can both validate and expedite concept development and assessment/design. These modelling and simulation activities will result in <u>better informed</u> and more <u>confident</u> procurement. This empowers personnel through informed decision making which in turn allows the acquisition process to proceed in a timely and cost-effective manner while increasing the likelihood of successfully acquiring the optimal system.

3.1.4 Conclusions

Humans are limited in their ability to process information. As such, the abilities and limitations of operators must be considered whenever a human-machine system is under consideration. The CSE framework that was developed in the TAMSS SA project provides a structure for modelling and simulation activities. The CSE framework is central to SBE: the CSE framework provides both a conceptual structure and strong methodological guidance for SBE activities. In particular, the CSE-based modelling and simulation requires the use of an evaluation process whereby specific variables are systematically manipulated and the impact on the operators' SA, workload and performance are measured.

The TAMSS SA project unequivocally demonstrated that the fidelity of the TAMSS simulation environment is sufficient to support simulation-based evaluation of CH-146 technologies. Specifically, the TAMSS SA project demonstrated that the fidelity obtained with a relatively inexpensive simulation environment based on PC platforms is sufficient for exercising and measuring the impact of technology (e.g., heads-up displays, ERSTA-like sensor capabilities) in the CH-146. The project also demonstrated that complex, accurate and relevant data can be obtained using PC-based simulation tools. Finally, the project showed how High-Level Architecture (HLA) can be used to connect distributed models in a manner that is achievable in simulation-based acquisition programs.

4. Integration Into Training

Throughout the conduct of the work associated with the establishment of a CH-146 simulation environment at the Carleton University CACR, as well as throughout the conduct of experiments, it became readily apparent that NTS-like devices had the potential to serve a far broader range of applications than those exercised during the performance of the TAMSS SA project. Comments were received from industry and government that alluded to such potential; the most frequent of which was associated with the potential application of NTS-like devices to the domain of training. The following sections describe these potential applications to training in greater detail and explore the nature of modifications to the NTS system that are believed to be required in order to pursue such applications.

4.1.1 Training

In order to meet the experimental requirements of the TAMSS SA project the NTS system was outfitted with low- to medium-fidelity representations of CH-146 avionics systems and flight controls. As has been described in detail in previous sections of this document, the avionics systems were represented in a variety of fashions, including virtual representations presented on flat panel displays (fitted with touch screens), as well as with simulated bezels and control panels. The resulting cockpit environment was described by numerous operators and visiting Subject Matter Experts (SMEs) as being applicable to training activities coincident with Part-Task Training (PTT), Cockpit Procedures Training (CPT), Tactics Training and Mission Rehearsal requirements.

4.1.1.1 Tactics Training and Mission Rehearsal

Tactics Training and Mission Rehearsal systems must allow operators to fly a simulated CH-146 Griffon in a tactically relevant synthetic environment. The purpose of a Tactics Trainer is to teach a crew how to correctly employ their tactical equipment in an operationally relevant and crewed environment (as opposed to learning how to operate the equipment in an artificially tranquil environment). As such, the effective management of crew resources is also a benefit of a Tactics Training system. Unlike a Full-Motion Flight Simulator (FMFS), the intent of a Tactics Trainer is not to teach “hands-and-feat” operation of the aircraft, nor is it intended to teach emergency procedures.

4.1.1.2 Cockpit Procedures Training

The purpose of a CPT is to provide a simulated cockpit environment that allows a crew to familiarize themselves with aircraft systems. Typically, a CPT takes the form of a full scale, functional replica of an aircraft cockpit. A CPT should allow routine and critical cockpit procedures to be learned, thus reducing the amount of time being demanded of the real aircraft or FMFS. An intent of a CPT is to teach the location and feel of cockpit controls. As such, it must provide a tactile representation of the cockpit that affords an opportunity to the crew to physically interact with all switches, flight controls and instruments. Crew Resource Management (CRM) and cooperation can also be taught in a CPT. The simulated environment of a CPT should include all visual and auditory cues, so as to allow the crew to identify cause and effect relationships associated with the operation of aircraft systems.

4.1.1.3 *Part-Task Training*

Part-Task Trainers focus on the training surrounding a specific aircraft system or group of systems. A PTT should afford an individual crew member with the ability to interact with a simulated system, without the need to occupy a higher fidelity system (i.e. CPT, TT or FMFS). Systems such as the Control Display Unit (CDU) are ideal candidates for PTT since they are complex in nature, but can be isolated, to a degree, from the rest of the cockpit. In certain instances, a realistic tactile interaction with a system of focus may be required. However, in many cases interaction with virtual representations of aircraft systems will be adequate.

4.1.1.4 *Current Limitations of the NTS*

The NTS was found to have limitations that would preclude the use of the system, in its present state, in supporting a training regimen (TT, PTT or CPT). These limitations are described as follows:

1. *Level of Software Maturity.* The NTS system was designed to fulfill the needs of a Technology Demonstration Project (TDP), specifically that of the TAMSS TDP. The nature of the TAMSS TDP resulted in design goals for the NTS system that were not intended to provide scalability and longevity beyond the end-date of the TDP. As such, the level of maturity of much of the software that was developed to facilitate the integration of the COTS components that comprise the NTS is not suitable to form the foundation for a training system.

2. *Stability.* Related to point (1), the stability requirements of a system that will be used to deliver training are different from those used to support experimentation. For the purpose of this

discussion, “stability” is used to refer to the period of time over which a system can be observed to operate correctly, absent of any error of sufficient severity as to compromise the validity of the task being performed. Stability can be likened to a measure of Mean Time Between Failures (MTBF) for simulator systems. A system that will be used to deliver training has a more stringent requirement for stability than a system used to support experimentation such as that conducted under the TAMSS SA project due to the potentially negative impact upon training that could result from system failure. Although the NTS, under careful supervision of the CACR staff, was found to sufficiently stable to conduct SA experiments, it is not felt that the system is stable enough in its present form to support training.

3. *Open Architecture.* Simulation systems, in general, benefit from an open architecture. “Open Architecture” is a term used to describe a hardware or software design that has published specifications allowing third parties to develop add-on modules that can be easily incorporated into a system derived from the design. In this case, an open architecture will be of benefit to a training device by affording a flexible means of upgrading the device to match the evolving complement of equipment on the CH-146 Griffon helicopter. An open architecture is also of benefit due to the potential for component re-use which is fostered by a requirement for the development of modular systems that adhere to published specifications. Although portions of the NTS feature an open architecture, the scope of the system that is “open” is insufficient to result in a significant benefit in a training context.

4. *Focused Fidelity.* The fidelity requirements of PTT- and CPT-level training devices will require the incorporation of cockpit elements that exceed those currently available in the NTS. These elements, such as switches and other controls associated with the fuel management system are examples of “focused fidelity”. That is, the attention to fidelity is focused on those parts of the cockpit that are deemed to be important to the training task, rather than mandating a specific level of fidelity to be applied to the representation of the entire cockpit. The NTS features focused fidelity for pieces of equipment relevant to the TAMSS TDP (CDU bezels, CSC panel) but lacks fidelity in other portions of the cockpit that will be important to TT-, PTT- and CPT-level training.

5. *Fidelity of Models of Aircraft Systems.* Although the NTS cockpit environment looks and feels like a CH-146 Griffon in

many respects, the models of aircraft systems that underlie the virtual instruments are generic in nature. The NTS representations of the fuel system, electrical system, hydraulic system and engines are built upon representations available in the commercial HELISIM product, and were not developed using authoritative data for the Bell 412. In order to teach proper cause and effect relationships between these and other systems, a higher fidelity representation of these systems must be developed or integrated.

4.1.2 Summary

Significant modifications would be required in order to prepare the NTS for use in a training regimen. However, the potential role for NTS-like devices in a vertically integrated training program should not be underestimated. SMEs who participated in TAMSS SA experiments expressed unsolicited support for the notion that upgraded NTS-like simulators could directly support tactics training, mission rehearsal and doctrine development. One SME noted:

"Quantum mission improvements were obvious from one mission simulation to the next, and we never turned a real rotor."

The consideration of applicability to PTT and CPT tasks were made in order to explore the applicability of an NTS-like device to a vertically integrated training solution, such as that represented by the Integrated Simulation Training System (ISTS) concept currently circulating within the Canadian Forces.

5. References

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Annex A – ERSTA Model Architecture

CMC ELECTRONICS INC.

Development of TAMSS-ERSTA Rapid Prototype

Contract No. W8485-0-XKCF/01BQ/TI-02
CMC Project EA0058

MODELLING AND SIMULATION ARCHITECTURE SPECIFICATION

Version 002

26 Apr 2004

Prepared by

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Development of TAMSS-ERSTA Rapid Prototype

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CMC Project EA0058

MODELLING AND SIMULATION ARCHITECTURE SPECIFICATION

26 Apr 2004

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Version 002

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REVISION PAGE

VERSION	DESCRIPTION	RELEASE DATE
001	All Pages	16 Feb 03
002	Remove IR Function	26 Apr 04

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1 OVERVIEW

1.1 Modelling and Simulation Objective

The objective of the rapid prototype is to provide an Electro-optical Reconnaissance, Surveillance, Targeting and Acquisition (ERSTA) Human Factors Engineering (HFE) mock-up to support Situational Awareness (SA) studies conducted by the Carleton University Centre for Applied Cognitive Research (CACR) for the Tactical Aviation Mission System Simulation (TAMSS) SA Technology Demonstration Project (TDP). The Situational Awareness Studies are an important component of TDP as they will help to formalize the requirements capture process essential to Simulation Based Acquisition (SBA). TAMSS is an approved Defence R&D Technology Demonstration Project.

The Air Force requires improved Modelling and Simulation (M&S) capability to support SBA, mission rehearsal, human factor assessments and training. The TAMSS project will focus on M&S for Acquisition. TAMSS will use distributed and local M&S techniques to link high fidelity Defence Research Establishment (DRE) component models with CH146 crew station simulators for system and crew in the loop system assessments.

There are three overall objectives (or Measures of Effectiveness (MOE)) by which the project's progress shall be measured by the DND Senior Review Board.

a. MOE#1: Establish a distributed high fidelity networked CH146 virtual environment.

b. MOE#2: Contribute three post graduate level studies in SA to the open literature.

c. MOE#3: Conduct one validated operational test/evaluation to demonstrate the role of simulation in the acquisition process.

The objectives of MOE#1 and MOE#3 are being addressed in large part through the TAMSS Systems Integrator Contract.

The TAMSS Situational awareness studies contract with CACR addresses objective MOE#2. Work by the CACR will include a series of three SA studies to examine pilot crew options in a virtual simulation. As part of the SA studies contract, a CH146 Griffon Networked Tactical Simulator (NTS) has been built for the CACR. The CH146 NTS allows the crews to be immersed in a virtual simulation of a tactical environment. The task of CMC Electronics is to integrate the ERSTA HFE mock-up with the CH146 NTS to augment the SA Studies conducted by CACR.

The ERSTA HFE mock-up was designed to conduct human factors experimentation of the operator station using an aircraft FLIR system. For the purpose of the CACR studies, a simulated ERSTA system is required. This ERSTA system will have to be a generic representation, since the system has not been purchased for the CH146 fleet.

1.2 Functional Prototype Components

The ERSTA HFE mock-up will provide the following functional components:

a. A sensor simulation system to simulate a Colour Day TeleVision (CDTV) System.

b. A virtual scene displays (CDTV) to simulate real-time video display of sensor imagery.

c. A tactical map display to show information received from the NTS.

d. A cockpit map display to show information received from the NTS.

e. A communication system (HLA) to communicate with NTS.

f. A Centre Console Instrument Display to show instruments and a second virtual scene (CDTV).

g. Forms to send and receive messages.

h. A system manager to start up all of the above components.

1.3 External Interfaces

Since the prototype software is driving graphics, the workload is relatively heavy. To divide the workload, three personal computers are used to implement different tasks. The three personal computers are connected through a network and all the external interfaces are identified in the drawing Figure 1 as connections in or out of the four computers. These include a Joystick, a Keyboard, Video, Mouse (KVM) switch and a hub.

1.4 States and Modes

There are four states for the TAMSS rapid prototype: Off, Initialization, Run and Shutdown.

The operator is required to transit from the Off state to Initialization State by starting the System Manager. The system automatically transitions from the Initialization State to Run State. And the operator is required to initiate the state transition from Run to Shutdown by pressing a designated shutdown key.

There are no special modes for the above four states.

2 HARDWARE ARCHITECTURE

2.1 Component Overview

The ERSTA HFE mock-up will include the following hardware components:

a. Three desktop computers
b. Four flat panel, colour monitors (including two touch-screen monitors)
c. Two standard keyboards and mice
d. A KVM switch
e. A Hub
f. Two Joysticks (One Joystick and One Game Pad)
g. One Cereal Box

Additionally, two instrument displays will be added to the NTS as shown in Figure 1. Except for the inclusion of a sensor video window in the centre display, these two cockpit displays are not part of the ERSTA mock-up and therefore will be not described here.

2.2 Desktop Computers

One computer is needed to drive CDTV sensor images with a resolution of approximately 640 x 480 (refer to Section 2.3) at a minimum rate of 60 frames/second. To achieve this rate, large process memory (RAM), large video memory and high-speed computers are needed. Single Pentium3 1.8GHZ CPU, 1024M RAM, 128M video memory computers are selected to drive the visual simulation images.

Another two computers need to drive map displays with a resolution of approximately 1024 x 768 and 800 x 600 (refer to Section 2.3). The maps will be shown on the Tactical Map display and Cockpit Map Display separately. To meet this workload, dual Pentium3 1.8GHZ CPU, 1024M RAM, 128M video memory computers are selected to drive the two map graphics. Sensor simulation, Video Image and Forms will be developed and run on one of these two computers (Refer to 3 Software Architecture).

2.3 Flat Panel, Colour Touch-screens

The are two Viewsonic VP151 monitors (Touch-Screen). One monitor will be used as Tactical Map Display, set at 1024 x 768 resolution to display Tactical Map. The other one will be used as Visual Simulation Display, set at 768 * 1024 (Rotated) to display the sensor image (CDTV) and forms in the up-down layout (Touch function is not used for this display) .

The NTS system has two NEC 2010X monitors to be used as Pilot Flight Instruments Display and Co-pilot Flight Instruments Display. These two displays are drawn in the Figure 1 TAMSS-ERSTA Prototype Architecture and Figure 3 TAMSS-ERSTA System Configuration since they will be used in conjunction with other displays. To maintain consistency among the instrument displays, a NEC 2010X monitor is chosen as the Centre Instrument Display.

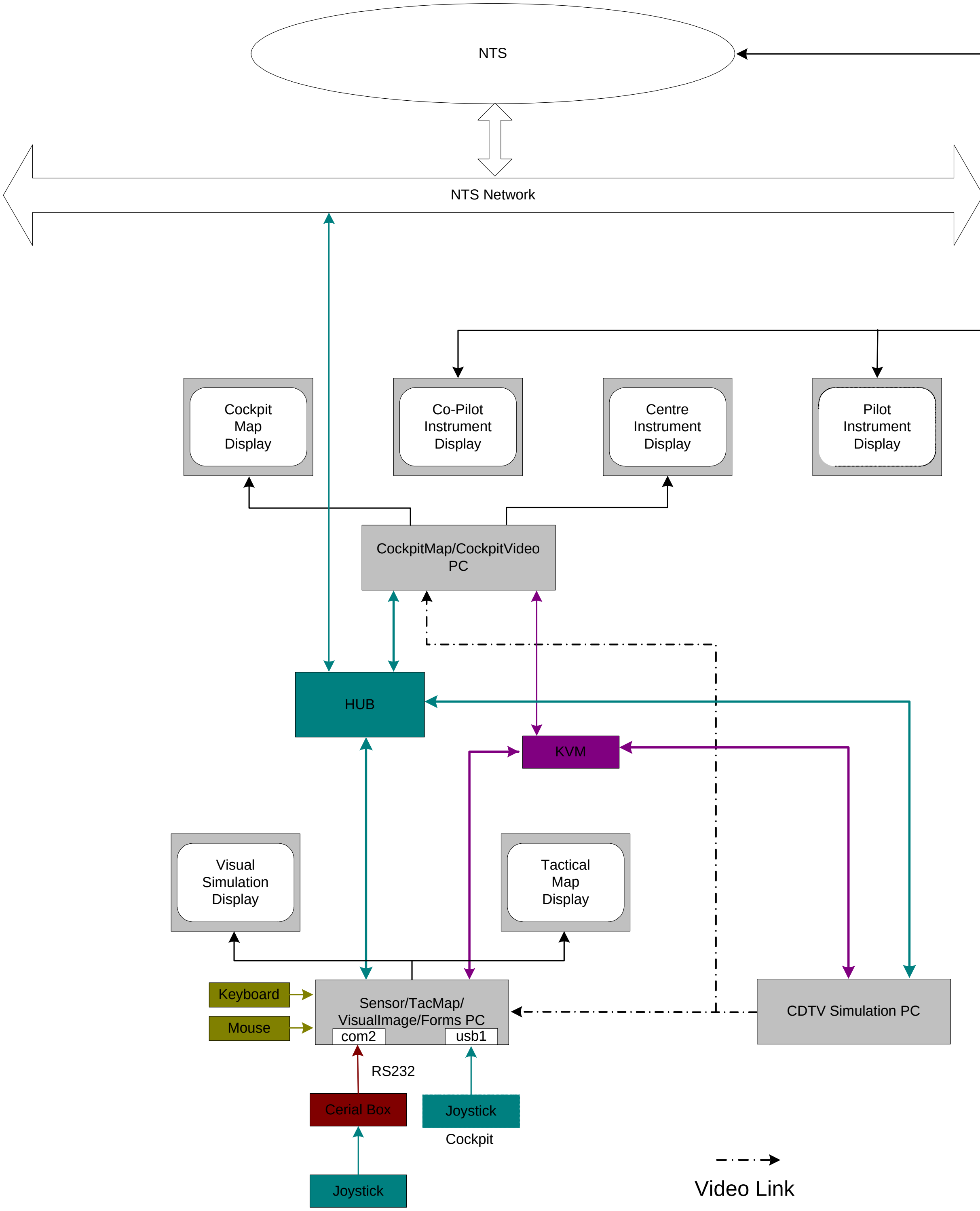

Figure 1 TAMSS-ERSTA Prototype Architecture

A 12'' Touchtek monitor (Touch Screen) is used as Cockpit Map Display setting at 800 * 600 to display the Cockpit Map

2.4 Standard keyboards and mouse

Two standard PC keyboard and a standard mouse will be connected to the PCs using the PS/2 input. One keyboard and the mouse will be connected to Harry (Figure 3) for the Form inputs and starting the applications. The other keyboard will be connected to Hagrid (Figure 3) to shutdown the applications. Using a separate keyboard for shutdown is to prevent the operators from shutting down the system by mistake.

2.5 KVM system

A SwitchView SV831 KVM system is connected to the PCs. The purpose of using the switch is to easily switch between the computers. It is intended only for use in development and testing.

2.6 Hub

The hub is used to set up the network connecting the ERSTA HFE mock-up to the NTS and enabling the internal communication within the ERSTA HFE mock-up.

2.7 Joysticks

There are two joysticks used for the ERSTA HFE mock-up. One is for the Cabin operator and the other is for the co-pilot. An existing bilateral handgrip joystick will be used for the Cabin operator. The analog and discrete outputs of the joystick are captured by a cereal box (refer to Section 2.8) and forwarded via RS-232 serial communications to the sensor computer. A Logitech Wingman Rumble Pad will be used for the co-pilot and will connect to the sensor computer (Harry, Figure 3) using USB. The original switch functionality was defined in the Human Engineering Design and Approach Document – Operator (**HEDAD-O** [Ref 1]). However some functions need to be redefined based on the ERSTA mock-up requirements, and mapped to the two different control devices.

2.8 Cereal Box

There is a cereal box used to interface the cabin joystick to the sensor computer. The cereal box transforms and packages the control input data for transmission to the sensor computer over an RS-232 serial communication interface.

3 SOFTWARE ARCHITECTURE

3.1 Component Overview

There are two basic requirements for the ERSTA mock-up:

- One visual simulation images will be shown on the Visual Simulation Display and Centre Instrument Display based on the sensor simulation.
- Two map graphics will be shown on the Tactical Map display and Cockpit Map Display.

To meet the basic requirements, one visual simulation processes will be developed to simulate a CDTV image so that it can be captured and displayed in different sizes and layouts on the different monitors. Another two processes will be developed to capture and show the image on the displays.

The whole TAMSS-ERSTA system software therefore has twelve major components including nine executable processes and three databases.

Processes:

a. System Manager
b. HLA
c. Sensor Simulation
d. CDTV Visual Simulation
e. Tactical Map
f. Cockpit Map
g. Forms
h. Cockpit Video (Video Capture)
i. Visual Images (Video Capture)

Databases:

a. Configuration Database
b. Visual Simulation Database
c. Map Database

Experimental data will be recorded. The data recording process is on the NTS side so it is not included in the TAMSS-ERSTA system software. However, the sensor simulation will send sensor and visual data to the recording process. For this reason the data recording process is still drawn in the software architecture.

Figure 2 illustrates the software architecture which identifies the links of all the components. The software will be implemented using C/C++, VEGA, OpenGL and VR_LINK.

3.1.1 C/C++

C/C++ is the fundamental tool for the software development. It has the following good points:

- C/C++ allows the manipulation of bits, bytes and addresses- the basic elements with which the computer functions.

- Its portability makes it possible to adapt software written for one type of computer to another.

- All other application software VEGA, OpenGL and VR_LINK are built on C/C++.

C/C++ is chosen as the basic tool to develop the TAMSS-ERSTA rapid prototype software.

3.1.2 VEGA

VEGA is a software environment for virtual reality and real-time simulation applications. By combining advanced simulation functionality with an easy-to-use tool, VEGA provides a means of constructing sophisticated applications quickly and easily. It has the following features:

- Well used in the airline transportation, aircraft manufacturing, space and defence industries

- Comes with an extensible point-and-click graphical user interface, enabling changes to significant application parameters without coding or re-compiling.

- Available in multi-process (MP) and single-process (SP) configurations and offers a low cost solution for systems with a single CPU and supports the development of applications using a single process runtime model.

Based on these features VEGA is the major development tool for the Out-The-Window (OTW) scene of the CH146 Griffon Networked Tactical Simulator (NTS) which has been built for the CACR. To be consistent with the existing NTS system and build high fidelity sensor simulation images, VEGA is chosen as a development tool for CDTV and TIS visual simulation.

The Vega FX module is also being used to provide the simulation of entity interactions such as smoke and flame when an object is damaged within the scenario.

3.1.3 OpenGL

OpenGL is an environment for developing portable, interactive 2D and 3D graphics applications. It is the industry's most widely used and supported 2D and 3D graphics application programming interface (API), bringing thousands of applications to a wide variety of computer platforms. VEGA is built upon OpenGL. It has the following advantages:

- Industry standard with broad support

- Stable and available on a wide variety of platforms.
- Reliable and portable
- Evolving
- Scalable
- Easy to use
- Well-documented

For these advantages and features, OpenGL is selected to implement Tactical and Cockpit maps and all the overlays on the CDTV and TIS displays.

3.1.4 VR_LINK

The VR_LINK library is used to implement HLA interface for communications with the NTS specified in the SOW [Ref 3]). HLA is the industry standard method of inter-simulation communications. Additionally, the use of HLA will facilitate the future use of a modified ERSTA prototype with other simulations.

3.2 System Manager

The task of the system manager is to start the other processes locally or remotely. “Locally” means to start processes on the same computer. “Remotely” means to start the processes on different computers. It saves time and trouble that will be required to start each process separately. The process is implemented using C/C++.

3.3 HLA

The HLA interface is intended to handle all HLA communications. The data received via HLA will then be placed in an internal format that is appropriate for use by other modules. This module will be written in C/C++ using the appropriate VR_LINK libraries.

3.4 Sensor Simulation

The sensor simulation process simulates the functions of a real sensor. The process has two modules: I/O handler and sensor.

3.4.1 I/O Handler

I/O handler takes the analog and discrete outputs from the cereal box which captures joystick and switch events, then transfers the data to the Sensor Simulation Module. This module is implemented in C/C++.

3.4.2 Sensor

The Sensor emulates the functionality of the sensor ball. The functions include:

- Pan and tilt
  Use joystick to control pan and tilt.

- Zoom
  Be able to zoom in and out.

- Rangefinding
  Determine the range of anything in the boresight.

- Slew to Aircraft Reference Position (ARP).
  The sensor is able to slew to a specified position with respect to the nose of the aircraft.

- Slew to Position on the Map.
  The sensor is able to slew to a specified position on the map.

- Auto-tracking
  The sensor is able to track still and moving objects without pan/tilt control.

- Designating
  Find the target position to be designated.

The sensor module is implemented using C/C++.

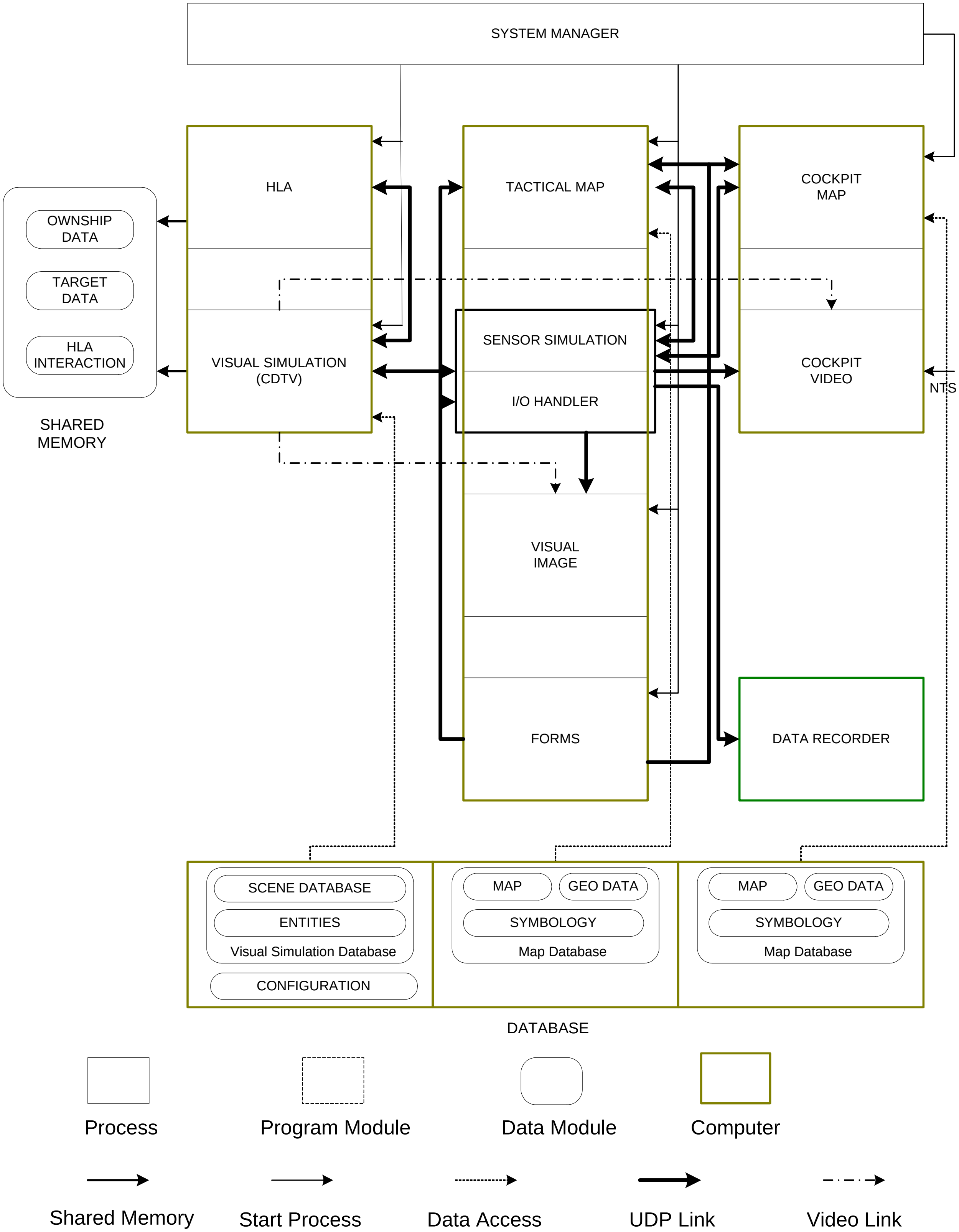

Figure 2 TAMSS-ERSTA Software Architecture

3.5 CDTV Visual Simulation

The CDTV Visual Simulation process simulates the image from a Color Day TeleVison which is installed inside the sensor ball. It has the following functions:

– Functions

a. Dynamically add, locate and remove entities of ground vehicles, aircraft and missiles.
b. Make smoke and fire when the entities are damaged.
c. Zoom in and out
d. Find an object when the auto-tracker run mode is selected
e. Provide corresponding visual of the sensor.

– Overlays
a. Sensor position and orientation
b. Reticule
c. Track Window
d. Zoom box
e. Run mode
f. Sensor controller
g. Range and Bearing
h. Zoom
i. Designating

The CDTV Visual Simulation is implemented in C/C++ using VEGA and OpenGL libraries.

3.6 Visual Image

The process grabs video signals produced by the CDTV Visual Simulation and displays the video image on the Visual Simulation Display. The functions of this process includes:

– Display Images
Display the CDTV image.

The process will use the ATI Video Card and Microsoft DirectX9.0.

3.7 Cockpit Video

This process grabs video signals produced by the CDTV Visual Simulation and displays the video image on the Cockpit Instrument Display. The functions of this process includes:

– Display Images
Display the CDTV image.

The process will use the ATI Video Card and Microsoft DirectX9.0 and is started with the Centre Instrument Display which is on the NTS side of the Network.

3.8 Tactical Map

The map process provides a two-dimensional map with overview of the tactical and operational areas of interest. The map is based on military map formats. The tactical map implements the following functions:

- Scale and Magnification
  The user is able to zoom in to look at a small area or zoom out to look at the surroundings.

- Tactical Features
  Display and identify phase lines, points, routes, tracks, borders and zones.

- North Up and Heading Up Orientation Mode
  North up mode always keeps north in the up direction. The aircraft symbol rotates when the heading changes. Heading up mode always keeps the aircraft heading in the up direction. The map rotates when the heading changes.

- Aircraft Symbol
  A symbol is used to clearly identify the aircraft position, heading, sensor orientation and field of regard.

- Map Overlays
  Import and export tactical traces including:
  a. enemy or threat disposition;
  b. friendly disposition;
  c. control measures (phase lines, unit or formation boundaries etc).
  d. obstacle Plan;
  e. tactical Update and /or Handover; and
  f. custom “personal” overlay created to allow the user to de-clutter.

The map process is implemented in C/C++ using the OpenGL library.

3.9 Cockpit Map

Like the Tactical Map, the Cockpit Map process provides a two-dimensional map with an overview of the tactical and operational areas of interest. It has the same functionality as the Tactical Map (Refer to Section 3.8). However the Cockpit Map can be manipulated independently from the Tactical Map.

The map process is implemented in C/C++ using the OpenGL library.

3.10 Forms

The process provides a graphic user interface to fill out a report at run time. The process will be implemented using Visual Basic. The forms include:

- Main form to provide menu for choosing other forms,
- Contact form,
- Close Air Support (CAS) form.

3.11 Database

All data manipulated by the above components are accessed or saved in a database. The database includes three major parts: Configuration Files, Visual Simulation Database, Map Database

3.11.1 Configuration Files

The configuration files store the initial parameters used by the above processes.

3.11.2 Visual Simulation Database

The database stores the scene database (Gagetown terrain) and all the entity models that will be used in the Visual Simulation module.

3.11.3 Map Database

The database stores the Gagetown map, all symbology and the geographic data for the tactical features used in the Tactical Map and Cockpit Map process.

4 SYSTEM CONFIGURATIONS

As shown in the hardware architecture (Refer to Section 2 Hardware Architecture), three computers will be used to support the whole system. The computers will communicate with each other over Ethernet. The joysticks are connected into the sensor computer through an RS232 serial port and one USB port. All the processes except Cockpit Video will be started by System Manager. The processes are designed to be easily moved to the other computers, that is, to remove a process executable file from one computer and install it on another computer. The system configuration is shown as Figure 3.

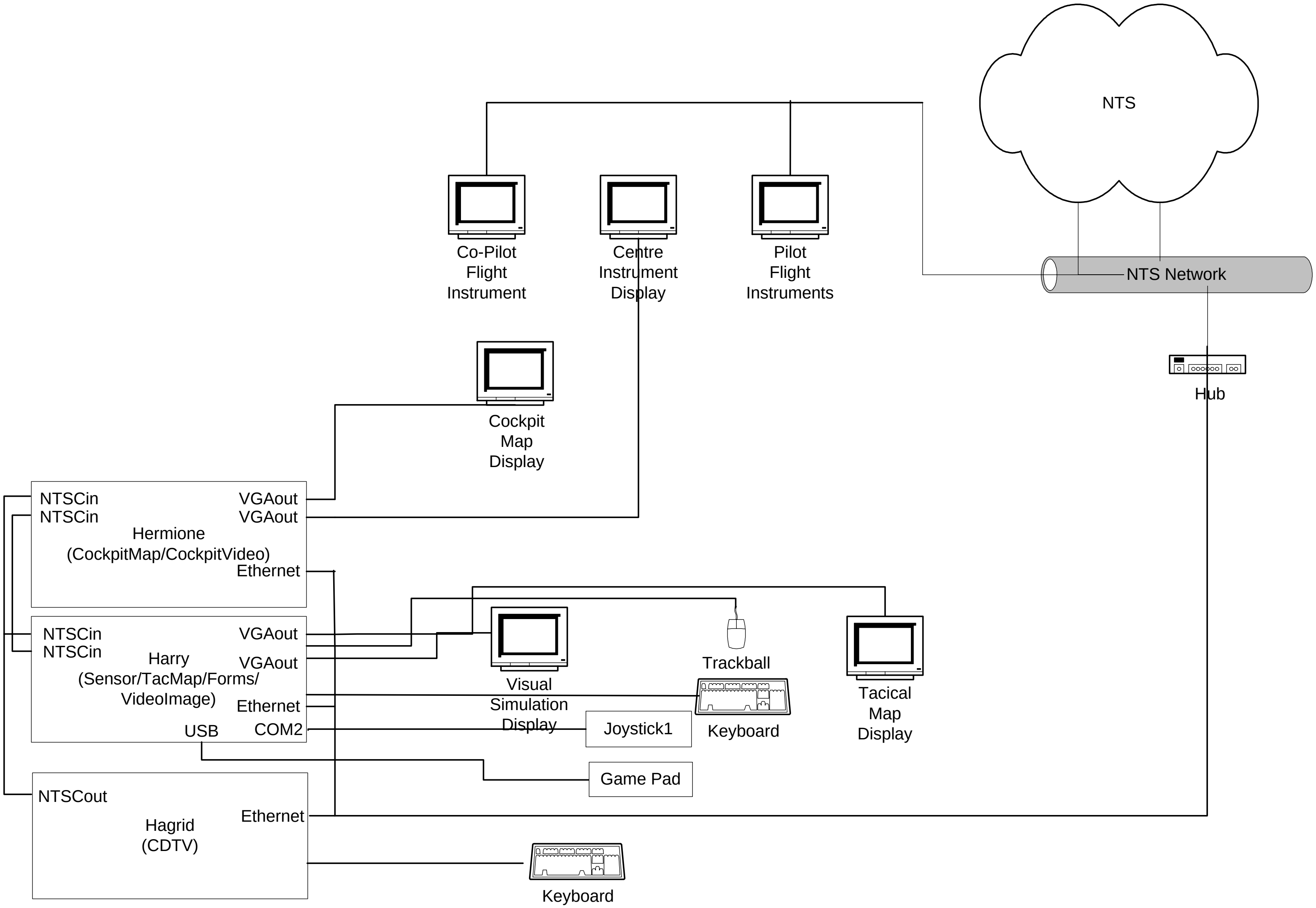

Figure 3 Stage 2 (Experiment #3) TAMSS-ERSTA System Configuration

Figure 4 is the physical equipment layout for the experiments.

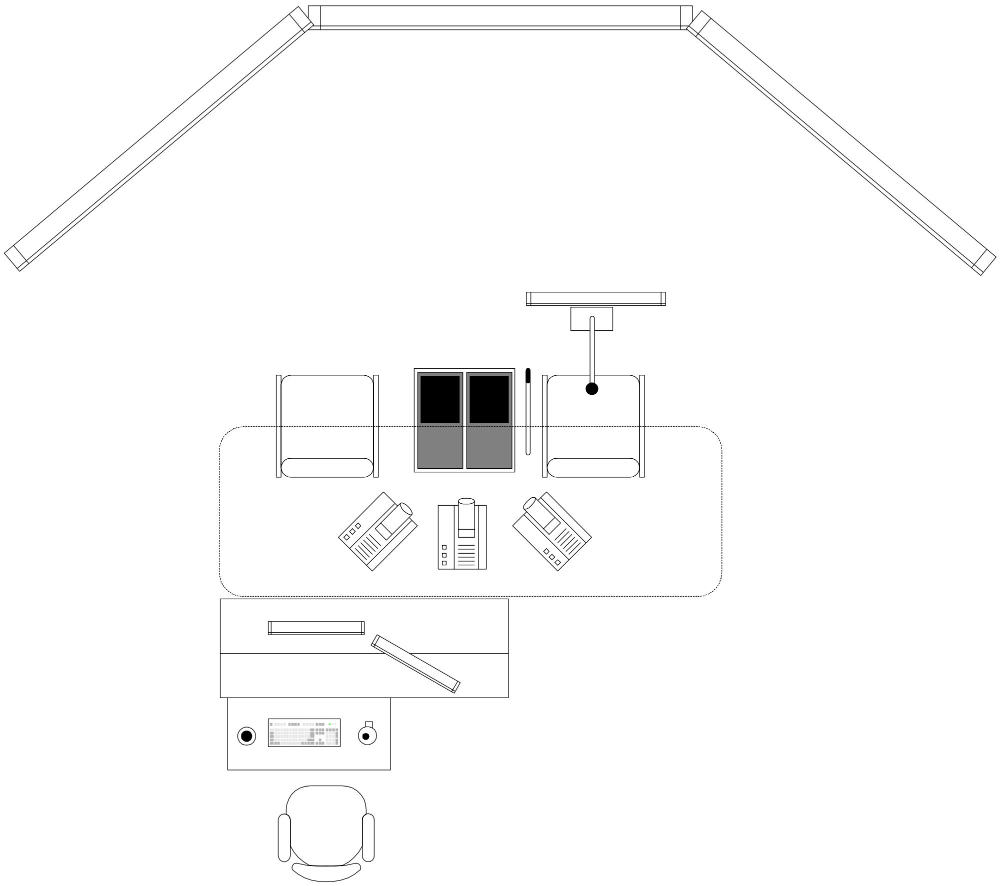

Figure 4 TAMSS-ERSTA System Layout

5 DIRECTORY STRUCTURE

Windows Version Control System (WinCVS), version 1.3, will be used to control access to source code and to manage internal releases. Figure 5 shows the directory structure. All the computers will use the same configuration.

```
Common\: Source, header and library files used for all
processes
Database\:
        Map\:
                Geodata\:  All geographic data
                Maps\: All maps
                Symbology\: All symbologies
        Visual\:
                Entity\: All entities
                Scene\: Gagetown Scene database
Documentation\:
        ArchSpec\: Architecture Specification
        DevPlan\: Development Plan
        VDD\:  Version Description Documentation
Include\: Include files from all the process
Library\:
Process\:
        CDTV\: CDTV Workspace
        CDTV_video\: CDTV_video Workspace
        CockpitMap\: CockpitMap Workspace
        Forms\: Forms Workspace
        HLA\: HLA Workspace
        Sensor\: Sensor Workspace
        SysMag\:
                Launcher\: Launcher Workspace
                Manager\: Manager Workspace
        TacMap\: Tactical Map Workspace
```

Figure 5 Directory Structure for TAMSS-ERSTA SA

6 SOFTWARE DEVELOPMENT ENVIRONMENT

6.1 Hardware

- Three Pentium III Computers with:
  - single or dual processor,
  - 64 MB RAM (minimum),
  - OpenGL-based graphics card with at least 32 MB texture memory.
- The Sensor/TacMap/VideoImage/Form computer must have two serial ports, one USB port and one ATI video card.
- The CDTV computer must have video output.
- The CockpitMap/CockpitVideo must have one serial port, one ATI video card.
- One Video splitter
- Two Standard Keyboards
- One Track ball or mouse
- Two Joysticks
- Two touch-screen monitors and two standard monitors.
- One Hub

6.2 Operating System

Windows 2000

6.3 Software

- VEGA Developer licence and VEGA running licence with Special Effect (FX) module
- MAK VR_LINK Licence
- DMSO RTI1.3NG Version 6
- Microsoft Visual C++ V6.0 or later
- OpenGL Libraries
- Microsoft Visual Basic V6.0 or later
- Touch display driver

- Display rotation software

6.4 Data and Databases

Gagetown Scene Database

Entity Models in Open Flight Format

Gagetown Maps

Military Standard Symbologies

Geographic Data for Tactical Features

7 REFERENCED DOCUMENTS

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8 ABBREVIATIONS, ACRONYMS, AND DEFINITIONS

AOI	Area of Interest
ARP	Aircraft Reference Position
CACR	Carleton University Center for Applied Cognitive Research
CMC	CMC Electronics Inc.
CDTV	Colour Day TeleVision
DND	Department of National Defence
DRE	Defence Research Establishment
ERSTA	Electro-optical Reconnaissance, Surveillance, Targeting and Acquisition
FLIR	Forward Looking InfraRed
FOR	Field Of Regard
FOV	Field Of View
HFE	Human Factors Engineering
HLA	High Level Architecture
I/O	Input and Output
KVM	Keyboard, Video, Mouse switch
M&S	Modelling and Simulation
MOE	Measure of Effectiveness
NTS	Networked Tactical Simulator
R&D	Research and Development
SA	Situational Awareness
SBA	Simulation Based Acquisition
SOW	Statement Of Work
TAMSS	Tactical Aviation Mission System Simulation
TDP	Technology Demonstration Project

Annex B – ERSTA Model Version Description Document

Development of TAMSS SA Rapid Prototype

Contract No. W8485-0-XKCF/01BQ/TI-02
CMC Project EA0058

VERSION DESCRIPTION DOCUMENT

VERSION 002

April 12, 2004

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Development of TAMSS SA Rapid Prototype

Contract No. W8485-0-XKCF/01BQ/TI-02
CMC Project EA0058

VERSION DESCRIPTION DOCUMENT

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REVISION PAGE

VERSION	DESCRIPTION	RELEASE DATE
001	Stage 1 Release for Experiment #2	January 10, 2003
002	Stage 2 Release for Experiment #3	April 12, 2004

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1 CONFIGURATION

1.1 Overview

The TAMSS_SA rapid prototype project is being conducted to support the Situational Awareness (**SA**) studies for the Tactical Aviation Mission System Simulation (**TAMSS**) SA Technology Demonstration Project (**TDP**). The studies comprise three experiments:

- Experiment #1 uses only a Griffon cockpit simulation.
- Experiment #2 requires the addition of the cabin mission system, called the Electro-Optic Reconnaissance, Surveillance and Target Acquisition (**ERSTA**) system. In the first stage of ERSTA development, the focus was on the hardware setup and software foundation. The software components included in the ERSTA system for Experiment #2 are:
    - Sensor Simulation System
    - Colour Day TeleVision (**CDTV**)
    - Tactical Map
    - Cockpit Map
    - High Level Architecture (**HLA**)
    - Video Capture modules
    - Contact Form
    - System Manager
- Experiment #3 requires more interaction (firing) and allows the Mission Commander to operate the sensor in the ERSTA system. The major functions added into the ERSTA system for Experiment #3 are:
    - Artillery firing and entity status
    - Additional Joystick (Game Pad) for the Mission Commander to control the ERSTA system
    - Map grid for the operators easy to get positions
    - Close Air Support (**CAS**) Form, Fire Mission Form and Main Form

The detailed functions for Experiment #2 and additional functions for Experiment #3 in each process are listed in Table 1-1.

Although the Thermal Imager (**TI**) simulation described in the system architecture [Ref 1] was planned to be added to the ERSTA system for Experiment #3, this requirement was dropped by the customer.

Table 1-1 lists the completed software processes and associated functions.

Table 1-1 Completed Software Processes and Associated Functions

Process	Functionality	Experiment #2	Experiment #3
System Manager	Start up all other processes	Start Sensor, CDTV, HLA, Tactical Map, Cockpit Map, Video Image, Forms	
HLA Interface	Communicate with Networked Tactical Simulator (**NTS**)	Communicate with NTS for: • Ownship position and orientation • Entities interaction for creating and removing • Entities position and orientation	Entity interaction for the entity status
Sensor Simulation	Simulate the functions of a real sensor	Control: • One input/output (**I/O**) handler • Pan and Tilt • Zoom of CDTV • Range finding • Slew to Aircraft Reference Position (**ARP**) • Slew to a position on the map • Auto-tracking • Designating • Target marking	Control: • A second I/O handler • I/O controllers interaction
CDTV Visual Simulation	Simulate the image from a CDTV	• Get and move scene • Create and remove entities • Calculate range • Find object for auto-tracking	• Visual representation for artillery firing, bomb detonating and burning entities. • Visual representation for

Table 1-1 Completed Software Processes and Associated Functions

Process	Functionality	Experiment #2	Experiment #3
		• Overlays	the crashed entities. • Field of regard
Tactical Map Cockpit Map	A two-dimensional map with an overview of the tactical and operational areas of interest	• Moving Map • Scale and Magnification • Tactical Features • North up orientation • Aircraft Symbol • Overlays	• Heading up orientation • Orientation model switching • Map grid in Universal Transverse Mercator (**UTM**) coordinate. • Map grid ON-OFF switch • Map flip (only Cockpit Map)
Forms	Graphical User Interface (**GUI**) to receive and send messages	• Contact Form	• Main Form • CAS Form • Fire Mission Form
Visual Image Cockpit Video	Grab video signals and display the video image on the Visual Simulation Display and the Cockpit Console Instrument Display	• Grab CDTV image	
Data Recording	Record data	• Record Data for Experiment #2	• Record Data Experiment #3

Figure 1-1 shows the system configuration for Experiment #3.

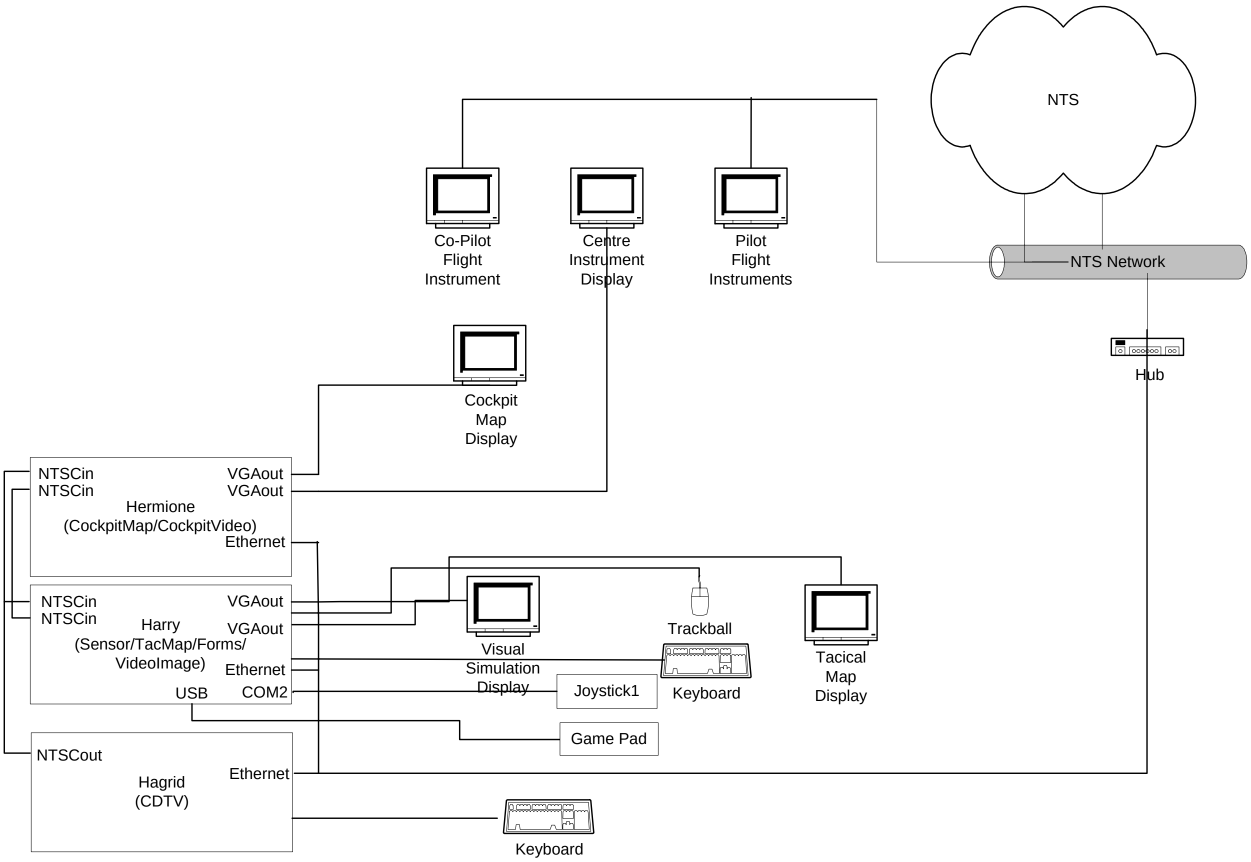

Figure 1-1 Stage 2 (Experiment #3) TAMSS-ERSTA System Configuration

1.2 Software Components

Table 1-2 lists the software components that must be used in order to start up and run the TAMSS Rapid Prototype application. All the executable files, configuration files and data files are stored in the following location of the corresponding computer: C:\TAMSS\Experiment3\Project\TAMSS_SA\. All the source code is saved on the company MKS. The data recording process saves data in a database on the NTS side of TAMSS.

Table 1-2 TAMSS Software Components

Software Component	Location	Functionality	Comments
Manager.exe	Harry-> C:\TAMSS\Experiment3 \Project\TAMSS_SA\Process\ Manager\	Start and run all the ERSTA applications	A shortcut, named Manager, is on the desktop on Harry. See footnote [1].
Scenario1.xml Scenario2.xml Scenario3.xml Scenario4.xml	Harry-> C:\TAMSS\Experiment3 \Project\TAMSS_SA\Process\ Manager\	Set up the path of all the software processes and scenario numbers	These files must be in Extensible Markup Language (XML) format and must be in the same directory as Manager.exe
Launcher.exe	Harry, Hagrid, Hermione-> C:\TAMSS\Experiment3 \Project\TAMSS_SA\Process\ Launcher\	Listen to the message from Manager.exe to start processes on local computers	A shortcut, named Launcher, is in the Start menu. The process will run automatically when the user logs into the computer
Sensor.exe	Harry-> C:\TAMSS\Experiment3 \Project\TAMSS_SA\Process\ Sensor\	Simulate a real sensor	
Map.exe (Tactical Map)	Harry-> C:\TAMSS\Experiment3 \Project\TAMSS_SA\Process\ Tactical Map\	Tactical map with overview of the tactical and operational areas of interest and overlays	
Maps Folder (12 Files in bitmap [.bmp] format)	Harry-> C:\TAMSS\Experiment3 \Project\TAMSS_SA\ Database\Map\	Gagetown map in tiles	The map files must have a .bmp extension
Symbology Folder (53 Files in tga format)	Harry-> C:\TAMSS\Experiment3 \Project\TAMSS_SA\ Database\Map\	Symbology (image files) for map overlays	The symbology files must have a .tga extension

[1] Manager.exe needs a scenario number as an argument. The number is currently set up in the shortcut icons of Manager (S1, S2, S3, S4 on the desktop). Refer to Appendix A "Start-up Procedure for the ERSTA Mock-up" for instructions on how to run the four scenarios.

Table 1-2 TAMSS Software Components

Software Component	Location	Functionality	Comments
Geodata Folder aco_N.xml custom_N.xml tactical_N.xml (N: 1-4)	Harry-> C:\TAMSS\Experiment3\Project\TAMSS_SA\Database\Map\	Geographic and Symbology data for map overlays	The geodata files must have a .xml extension
CDTV_Video.exe	Harry-> C:\TAMSS\Experiment3\Project\TAMSS_SA\Process\CDTV_TIS_Video\	Grab CDTV video signal and display it on Visual Simulation Display	
ERSTAForms.exe	Harry-> C:\TAMSS\Experiment3\Project\TAMSS_SA\Process\Forms\	ERSTA Forms	In Visual Basic
CDTV.exe	Hagrid-> C:\TAMSS\Experiment3\Project\TAMSS_SA\Process\CDTV	Simulate the image from a CDTV	See footnote [2]
Gagetown1.adf Gagetown2.adf Gagetown3.adf Gagetown4.adf	Hagrid-> C:\TAMSS\Experiment3\Project\TAMSS_SA\Process\Launcher\	Application Define File to define system and environment variables for each scenario	The files must be in the same folder as Launcher.exe
Gagetown Folder (20 files in fst format)	Hagrid-> C:\TAMSS\Experiment3\Project\TAMSS_SA\Database\Visual\Scene\	Gagetown database in tiles	

[2] CDTV.exe needs a scenario number as an argument. The number is set up in the scenarioN.xml (N: 1-4) files. The user does not need to change the files for Experiment #3.

Table 1-2 TAMSS Software Components

Software Component	Location	Functionality	Comments
GoodEntity Folder (20 model folders. Each folder includes files in .flt, .rgb, and .rgb.attr format)	Hagrid-> C:\TAMSS\Experiment3 \Project\TAMSS_SA\Database \Visual\Entity\	Entity models	• Files with a .flt extension are the model files. • Files with a .rgb extension are the texture files for the models. • Files with a .rgb.attr extension are the texture attribute files for the models.
HLATest.exe	Hagrid-> C:\TAMSS\Experiment3 \Project\TAMSS_SA\Process\ HLA	Communicate with NTS	
VegaStage.ini	Hagrid-> C:\TAMSS\Experiment3 \Project\TAMSS_SA\Process\ SysMag\Launcher\	The configuration file for HLATest.exe	The file must be in the same folder as Launcher.exe
VR_Link.fed	Hagrid-> C:\TAMSS\Experiment3 \Project\TAMSS_SA\Process \SysMag\Launcher\	The Federation definition file for HLATest.exe	The file must be in the same folder as Launcher.exe
RTI_Stage.rid	Hagrid-> C:\TAMSS\Experiment3 \Project\TAMSS_SA\Process\ SysMag\Launcher\	Run Time Infrastructure (**RTI**) initialization Data file to define data required by the RTI	The file must be in the same folder as Launcher.exe
Dis_eg_type	Hagrid-> C:\TAMSS\Experiment3 \Project\TAMSS_SA\Process\ SysMag\Launcher\	The entity model map file for HLATest.exe	The file must be in the same folder as Launcher.exe
Runlm.exe	Hagrid-> C:\bin\	Licence manager file to run HLATest.exe	This file must be running before starting HLATest.exe.

Table 1-2 TAMSS Software Components

Software Component	Location	Functionality	Comments
Lmdown.exe	Hagrid-> C:\bin\	Shutdown the licence manager file	Run this executable file only when required to force a licence manager shutdown
RunCDTVS1.bat RunCDTVS2.bat RunCDTVS3.bat RunCDTVS4.bat	Hagrid-> C:\TAMSS\Experiment3 \Project\TAMSS_SA\Process\ SysMag\Launcher\	A batch file to set path and start CDTV and HLA for each scenario	The file must be in the same folder as Launcher.exe
Map.exe (Cockpit Map)	Hermione-> C:\TAMSS\Experiment3 \Project\TAMSS_SA\Process\ Cockpit Map\	Cockpit map with overview of the tactical and operational areas of interest and overlays	
Maps Folder (12 Files in bmp format)	Hermione -> C:\TAMSS\Experiment3 \Project\TAMSS_SA\ Database\Map\	Gagetown map in tiles	The map files must have a .bmp extension
Symbology Folder (53 Files in tga format)	Hermione -> C:\TAMSS\Experiment3 \Project\TAMSS_SA\ Database\Map\	Symbology for map overlays	The symbology files must have a .tga extension
Geodata Folder aco_N.xml custom_N.xml tactical_N.xml (N: 1-4)	Hermione -> C:\TAMSS\Experiment3 \Project\TAMSS_SA\Database \Map\	Geographic and Symbology data for map overlays	The geodata files must have a .xml extension

1.2.1 Building Manager.exe

Table 1-3 lists the files included in the “Manager” project for Experiment #3.

Table 1-3 Manager.exe Source Code Files

File Name	Version	Functionality	Comments
SOURCE FILES (.CPP) MKS Server (srveng10:7001) d:\Groups\MKS\Development\HFE\TAMSS_SA_TI02\process\SysMag\Manager\			
Main.cpp	2.1	Send start up message to Launcher.exe on all the computers.	

Table 1-3 Manager.exe Source Code Files

File Name	Version	Functionality	Comments
HEADER FILES(.h) MKS Server (srveng10:7001) d:\Groups\MKS\Development\HFE\TAMSS_SA_TI02\Include\			
Ersta_communication_types.h	2.1	Structure and function definition of the UDP communications.	
udp_comm.h	2.1	UDP Communication.	
PerfTimer.h	2.1	Set timer.	
LIBRARY FILES MKS Server (srveng10:7001) d:\Groups\MKS\Development\HFE\TAMSS_SA_TI02\Library\			
timer.lib	2.1	Library file to set up timer.	
udp.lib	2.1	Library file for UDP communication.	
libexpat.lib		A library for parsing XML	

Before making any changes to files in the Manager folder, check out the whole workspace and all files in the project (from the MKS Server) to a Sendbox on a client computer.

Following a change to a file contained within the "Manager" project, a new Manager.exe can be generated as follows:

Step 1. Open the workspace in MS Visual Studio C++ 6.0 (Manger.dsw)

Step 2. In the Build Menu, select "Build sysmag.exe" or press F7.

Step 3. The path of the executable file (Manager.exe) has been already set to C:\TAMSS\Experiment3\Project\TAMSS_SA\Process\Manager\. The new executable file should be generated in that folder.

1.2.2 Building Launcher.exe

Table 1-4 lists the files included in the "Launcher" project for Experiment #3.

Table 1-4 Launcher.exe Source Code Files

File Name	Version	Functionality	Comments
SOURCE FILES (.CPP) MKS Server (srveng10:7001) d:\Groups\MKS\Development\HFE\TAMSS_SA_TI02\process\SysMag\Launcher\			
Main.cpp	2.1	Listens to the messages from Manager.exe to start the processes on its machine.	
HEADER FILES(.h) MKS Server (srveng10:7001) d:\Groups\MKS\Development\HFE\TAMSS_SA_TI02\Include\			
Ersta_communication_types.h	2.1	Structure and function definition of the UDP communications.	
udp_comm.h	2.1	UDP Communication.	
PerfTimer.h	2.1	Sets timer.	

Table 1-4 Launcher.exe Source Code Files

File Name	Version	Functionality	Comments
LIBRARY FILES MKS Server (srveng10:7001) d:\Groups\MKS\Development\HFE\TAMSS_SA_TI02\Library\			
udp.lib	2.1	Library file for UDP communication.	
timer.lib	2.1	Library file to set up timer.	

Before making changes to any files in the Launcher folder, check out the whole workspace and all files in the project (from the MKS Server) to a Sendbox on a client computer.

Following a change to a file contained within the "Launcher" project, a new Lancher.exe can be generated as follows:

Step 1. Open the workspace in MS Visual Studio C++ 6.0 (Launcher.dsw)

Step 2. In the Build Menu, select "Build Launcher.exe" or press F7.

Step 3. The path of the executable file (Lanuncher.exe) has been already set to C:\TAMSS\Experiment3\Project\TAMSS_SA\Process\Launcher\. The new executable file should be generated in that folder.

1.2.3 Building Sensor.exe

Table 1-5 lists the files included in the “Sensor” project for Experiment #3.

Table 1-5 Sensor.exe Source Code Files

File Name	Version	Functionality	Comments
SOURCE FILES (.CPP) MKS Server (srveng10:7001) d:\Groups\MKS\Development\HFE\TAMSS_SA_TI02\process\Sensor\			
Main.cpp	2.1	Initialize and update I/O handler and sensor module.	
JoysickJS.cpp	2.1	Gets user control data (Joystick) from cereal box.	
JoysickDX.cpp	2.1	Gets user control data (Game Pad) from cereal box.	
Sensor.cpp	2.1	Sensor simulation.	
HEADER FILES(.h) MKS Server (srveng10:7001) d:\Groups\MKS\Development\HFE\TAMSS_SA_TI02\Include\			
Ersta_communication_types.h	2.1	Structure and function definition of the UDP communications.	
Sensor.h	2.1	Header file for sensor.cpp.	
sensor_global.h	2.1	Header file define global variables used in both Joystick.cpp and Sensor.cpp.	
LatLong-Utmconversion.h	2.1	Header file used by the functions to convert between latitude and longitude and UTM coordinate.	
dataCollection.h	2.1	Header file for the data collection	
units.h	2.1	Units conversion	
SensorDataParams.h	2.1	Header file for data collection	
udp_comm.h	2.1	UDP Communication.	
PerfTimer.h	2.1	Sets timer.	
LIBRARY FILES MKS Server (srveng10:7001) d:\Groups\MKS\Development\HFE\TAMSS_SA_TI02\Library\			
udp.lib	2.1	Library file for UDP communication.	
timer.lib	2.1	Library file to set up timer.	
LLvsUTM.lib	2.1	Library file to convert between latitude and longitude and UTM coordinates.	

Before making changes to any files in the Sensor folder, check out the whole workspace and all files in the project (from the MKS Server) to a Sendbox on a client computer.

Following a change to a file contained within the "Sensor" project, a new Sensor.exe can be generated as follows:

Step 1. Open the workspace in MS Visual Studio C++ 6.0 (Sensor.dsw)

Step 2. In the Build Menu, select "Build Sensor.exe" or press F7.

Step 3. The path of the executable file (Sensor.exe) has been already set to C:\TAMSS\Experiment3\Project\TAMSS_SA\Process\Sensor\. The new executable file should be generated in that folder.

1.2.4 Building Map.exe (Tactical map and Cockpit map)

Table 1-6 lists the files included in the "TacMap" or "CockpitMap" project for Experiment #3.

Table 1-6 Map.exe Source Code Files

File Name	**Version**	**Functionality**	**Comments**
SOURCE FILES (.CPP) MKS Server (srveng10:7001) d:\Groups\MKS\Development\HFE\TAMSS_SA_TI02\process\Tactical Map\ (for Tactical Map) d:\Groups\MKS\Development\HFE\TAMSS_SA_TI02\process\Cockpit Map\ (for Cockpit Map)			
area.cpp	2.1	Create area overlays	
button.cpp	2.1	Create buttons	
flightplan.cpp	2.1	Create flight plan overlays	
GLF.cpp	2.1	Map indow frame	
glfont.cpp	2.1	Print texture texts	
label.cpp	2.1	Print texture labels	
lineseg.cpp	2.1	Create line segment overlays	
map.cpp	2.1	Get user control data from cereal box	
map_util.cpp	2.1	UTM and Screen coordinate conversions	
mytga.cpp	2.1	Load textures	
overlay.cpp	2.1	Draw overlays	
overlayobject.cpp	2.1	Create overlay objects	
ownship.cpp	2.1	Create ownship overlay	
symbol.cpp	2.1	Create symbol overlays	
HEADER FILES(.h) MKS Server (srveng10:7001) d:\Groups\MKS\Development\HFE\TAMSS_SA_TI02\Include\			
area.h	2.1	Header file for creating area overlays	
button.h	2.1	Header file for creating buttons	
ersta_communication_types.h	2.1	Structure and function definition of the UDP communications	
flightplan.h	2.1	Header file for creating flight plan overlays	
GLF.h	2.1	Header file for map window frame	
glfont.h	2.1	Header file for printing texture texts	
label.h	2.1	Header file for printing texture labels	

Table 1-6 Map.exe Source Code Files

File Name	Version	Functionality	Comments
LatLong-Utmconversion.h	2.1	Header file used by the functions to convert between latitude and longitude and UTM coordinate.	
lineseg.h	2.1	Header file for creating line segment overlays	
map.h	2.1	Header file for the map drawing	
map_util.h	2.1	Header file for UTM and Screen coordinate conversions	
overlay.h	2.1	Header file for drawing overlays	
overlayobject.h	2.1	Header file for drawing overlay objects	
ownship.h	2.1	Header file for drawing ownship	
mytga.h	2.1	Header file for loading textures	
symbol.h	2.1	Header file for drawing symbol overlays	
udp_comm.h	2.1	Header fiel for UDP Communication	
LIBRARY FILES MKS Server (srveng10:7001) d:\Groups\MKS\Development\HFE\TAMSS_SA_TI02\Library\			
udp.lib	2.1	Library file for UDP communication.	
timer.lib	2.1	Library file to set up timer.	
LLvsUTM.lib	2.1	Library file to convert between latitude and longitude and UTM coordinate.	
opengl32.lib		OpenGL Library	
glu32.lib		OpenGL Library	
glaux.lib		OpenGL Library	
ws2_32.lib		Win sock Library	
libexpat.lib		A library for parsing XML	

Before making changes to any files in the TacMap or CockpitMap folder, check out the whole workspace and all files in the project (from the MKS Server) to a Sendbox on a client computer.

Following a change to a file contained within the "TacMap" or "CockpitMap" project, a new Map.exe can be generated as follows:

Step 1. Open the workspace in MS Visual Studio C++ 6.0 (Map.dsw)

Step 2. In the Build Menu, select "Build Map.exe" or press F7.

Step 3. The path of the executable file (map.exe) has been already set to C:\TAMSS\Experiment3\Project\TAMSS_SA\Process\<TacMap or CockpitMap>\. The new executable file should be generated in that folder.

1.2.5 Building CDTV_Video.exe

Table 1-7 lists the files included in the "CDTV_Video" project for Experiment #3.

Table 1-7 CDTV_Video .exe Source Code Files

File Name	**Version**	**Functionality**	**Comments**
SOURCE FILES (.CPP) MKS Server (srveng10:7001) d:\Groups\MKS\Development\HFE\TAMSS_SA_TI02\process\CDTV_Video\			
Main.cpp	2.1	Grabs video signal from CDTV video image.	
HEADER FILES(.h) MKS Server (srveng10:7001) d:\Groups\MKS\Development\HFE\TAMSS_SA_TI02\Include\			
Ersta_communication_types.h	2.1	Structure and function definition of the UDP communications.	
udp_comm.h	2.1	UDP Communication.	
PerfTimer.h	2.1	Sets timer.	
LIBRARY FILES MKS Server (srveng10:7001) d:\Groups\MKS\Development\HFE\TAMSS_SA_TI02\Library\			
udp.lib	2.1	Library file for UDP communication.	
timer.lib	2.1	Library file to set up timer.	

Before making changes to any files in the CDTV_Video folder, check out the whole workspace and all files in the project (from the MKS Server) to a Sendbox on a client computer.

Following a change to a file contained within the "CDTV_video" project, a new CDTV_Video.exe can be generated as follows:

Step 1. Open the workspace in MS Visual Studio C++ 6.0 (CDTV_Video.dsw).

Step 2. In the Build Menu, select "Build CDTV_Video.exe" or press F7.

Step 3. The path of the executable file (CDTV_Video.exe) has been already set to C:\TAMSS\Experiment3\Project\TAMSS_SA\Process\CDTV_Video\. The new executable file should be generated in that folder.

1.2.6 Building ContactReport.exe

Table 1-8 lists the files included in the "Forms" project for Experiment #3.

Table 1-8 ERSTAForms .exe Source Code Files

File Name	Version	Functionality	Comments
SOURCE FILES (.CPP) MKS Server (srveng10:7001) d:\Groups\MKS\Development\HFE\TAMSS_SA_TI02\process\Forms\			
erstaSim_prj.vbp	2.1	ERSTA forms project	
main_frm.frm	2.1	Main form	
CAS_frm.frm	2.1	CAS form	
fireMsn_frm.frm	2.1	Fire Mission form	
sentbox_frm.frm	2.1	Message Sending form	
code.bas	2.1	Common settings	
Module1.bas	2.1	Common settings and functions	
ERSTA.mdb	2.1	Configuration file	Just make the form running

Before making changes to any files in the Forms folder, check out the whole workspace and all files in the project (from the MKS Server) to a Sendbox on a client computer.

Following a change to a file contained within the "Forms" project, a new ContactReport.exe can be generated as follows:

Step 1. Open the workspace in MS Visual Basic v6.0 (Forms.vbp)

Step 2. In the File Menu, select "Make ContactReport.exe".

Step 3. Move the executable to the appropriate folder (as described in Table 1-2).

Note: ContactReport is implemented in Visual Basic V6.0. Any changes or recompiling must to be carried out on a computer with Visual Basic installed.

1.2.7 Building CDTV.exe

Table 1-9 lists the files included in the "CDTV" project for Experiment #3.

Table 1-9 CDTV.exe Source Code Files

File Name	Version	Functionality	Comments
SOURCE FILES (.CPP) MKS Server (srveng10:7001) d:\Groups\MKS\Development\HFE\TAMSS_SA_TI02\process\CDTV\			
CDTV.cpp	2.1	Simulates the image from a Color Day TeleVision.	
Overlays.cpp	2.1	Draws overlays over the CDTV image.	
HEADER FILES(.h) MKS Server (srveng10:7001) d:\Groups\MKS\Development\HFE\TAMSS_SA_TI02\Include\			
Ersta_communication_types.h	2.1	Structure and function definition of the UDP communications.	
CDTV.h	2.1	Header file used by CDTV.cpp.	
cdtv_global.h	2.1	Header file to define global variables used by both CDTV.cpp and Overlay.cpp.	
shmem.h	2.1	Shared memory.	
udp_commM.h	2.1	UDP Communication for Multiple thread.	
units.h	2.1	Units conversion	
PerfTimer.h	2.1	Sets timer.	
LIBRARY FILES MKS Server (srveng10:7001) d:\Groups\MKS\Development\HFE\TAMSS_SA_TI02\Library\			
shmemMultipleThread	2.1	Library file for shared memory for multiple thread	
UDPM	2.1	Library file for UDP communication for multiple thread.	
timer.lib	2.1	Library file to set up timer.	

Before making changes to any files in the CDTV folder, check out the whole workspace and all files in the project (from the MKS Server) to a Sendbox on a client computer.

Following a change to a file contained within the "CDTV" project, a new CDTV.exe can be generated as follows:

Step 1. Open the workspace in MS Visual Studio C++ 6.0 (CDTV.dsw)

Step 2. In the Build Menu, select "Build CDTV.exe" or press F7.

Step 3. The path of the executable file (CDTV.exe) has been already set to C:\TAMSS\Experiment2\Project\TAMSS_SA\Process\CDTV\. The new executable file should be generated in that folder.

1.2.8 Building HLATest.exe

Table 1-10 lists the files included in the “HLATest” project for Experiment #3.

Table 1-10 HLATest .exe Source Code Files

File Name	Version	Functionality	Comments
SOURCE FILES (.CPP) MKS Server (srveng10:7001) d:\Groups\MKS\Development\HFE\TAMSS_SA_TI02\process\HLA\			
HLATest.cpp	2.1	Communicates with NTS	
ace.dll	2.1	Dynamic Library for HLA	
HEADER FILES(.h) C:\ cvsrepo\TAMSS _SA\Include\			
Ersta_communication_ types.h	2.1	Structure and function definition of the UDP communications.	
shmem.h	2.1	Shared memory.	
udp_commM.h	2.1	UDP Communication for Multiple thread.	
PerfTimer.h	2.1	Set timer.	
LIBRARY FILES C:\ cvsrepo\TAMSS _SA\Library\			
shmemMultipleThread	2.1	Library file for shared memory for multiple thread	
UDPM.lib	2.1	Library file for UDP communication for multiple thread.	
timer.lib	2.1	Library file to set up timer.	

Before making changes to any files in the HLA folder, check out the whole workspace and all files in the project (from the MKS Server) to a folder on a client computer.

Following a change to a file contained within the “HLATest” project, a new HLSTest.exe can be generated as follows:

Step 1. Check out the whole workspace and all files in the project to a folder.

Step 2. Open the workspace in MS Visual Studio C++ 6.0 (HLATest.dsw)

Step 3. In the Build Menu, select “Build HLATest.exe” or press F7.

Step 4. The path of the executable file (HLATest.exe) has been already set to C:\TAMSS\Experiment3\Project\TAMSS_SA\Process\HLA\. The new executable file should be generated in that folder.

1.2.9 Entity Name Consistency Issues

In order to correctly create, update and destroy entities for the CDTV image and Out-the-Window (**OTW**) scene, entity names must be consistent for processes on both NTS and ERSTA sides. Refer to Appendix B “The Structure of the Entity Name Map Files” for instructions on how to make the names consistent.

1.2.10 Entity Model Consistency Issues

To make the entities have the constant visual image on both OTW and the ERSTA sensor image, the same entity model and texture must be used. TAMSS_SA used the MAK 3D entity models and choose the forest (od) model texture for both OTW and ERSTA.

1.2.11 Scenario Set Up

There are a total of four scenarios for Experiment #3. Different configuration files must be set to run the four scenarios separately. The configuration files have already been created. They are as follows:

- GagetownN.adf (N: 1-4): Set correct position and entity models for CDTV video.
- Aco_N.xml (N: 1-4): Set Airspace Co-ordinate Order overlays.
- Tactical_N.xml (N: 1-4): Set tactical overlays.
- ScenarioN.xml (N: 1-4): Set up process path and scenario number for “Manager” process to start all ERSTA processes.

On Harry, the following four icons appear on the desktop: S1, S2, S3, S4. To start a scenario, just click on the corresponding icon. Refer to the "Start-up Procedure for the ERSTA Mock-up" in Appendix A.

1.3 Limitations

1.3.1 Map Coverage

During Stage 1, a 1:50K Gagetown Map was used. The map covers a range within the following latitudes and longitudes: East: 66° 35', West: 66°05', South: 45°25', North: 45°52'. Based on the scenario, the major activities will be occurring within this area. However, the starting point and ending point might be off the map. In this case, the map area background will be appeared as grey and only the overlays will be shown correctly.

1.3.2 Default Autoslew

The default Autoslew function was implemented, which points the turrets toward the nose of the aircraft, and is described in the HEDAD-O [Ref 1]. If no position has been designated on the map, and the Aircraft Heading Slew button or the Slew button on the joystick is pressed, the sensor will slew to the nose (pan zero/ tilt zero) of the aircraft by default.

2 INSTALLATION

For successful operation, all files (including executable files, configuration files and data files) must be located in the right directory, as indicated in Table 1-2.

2.1 Run ERSTA Software

2.1.1 Licenses

Install the following licences:

- Vega MP Runtime License for windows with basic module and special effects module (Fx) for CDTV.exe
- VR_Link License for HLATest.exe

In the TAMSS_ERSTA system for Experiment #3, a Vega MP Developer license (including running license) is installed on the computer/server designated as “Harry” (refer to Figure 1-1). The file CDTV.exe runs on the computer designated as “Hagrid”, to check out the running license from the server (Harry). The VR_Link License is developed and installed on Hagrid, and the file HLATest.exe rus on the same computer.

2.1.2 Applications

Install the DMSO RTI1.3NG Version 6 for HLATest.exe application.

In the TAMSS_ERSTA system for Experiment #3, the application is installed on Hagrid where HLATest.exe is running.

2.1.3 Environment

Perform the following additions/modifications on the computer operating system environment on Hagrid:

Step 1. Variable: MAKLMGRD_LICENSE_FILE (for HLATest.exe)
Value: @machine_running_mak_license_server, e.g. hagrid

Step 2. Variable: RTI_RID_FILE (for HLATest.exe)
Value: location_of_rid_file

Step 3. Variable: Path (Addition) (for HLATest.exe)
Value: c:\Program Files\DMSO\rti1.3ng-v6\win2000-vc6\bin

2.2 Recompile and Rebuild ERSTA Software

To recompile and rebuild the ERSTA software, all files (including Include Files, Library Files and Data Files) listed in Table 1-3 through Table 1-9 must be located in the correct directories as described in these tables.

2.2.1 Licenses

Install the following licenses:

Step 1. Vega Developer License with basic module and special effect module (Fx) for CDTV.exe

Step 2. VR_Link License for HLATest.exe

In the TAMSS_ERSTA system for Experiment #3, a Vega MP Developer license (including running license) is installed on the computer/server designated as “Harry” (refer to Figure 1-1). The file CDTV.exe runs on the computer designated as “Hagrid”, to check out the running license from the server (Harry). The VR_Link License is developed and installed on Hagrid, and the file HLATest.exe runs on the same computer.

2.2.2 Applications

Install the following applications:

Step 1. Vega Version 3.7.1 (For CDTV.exe)

Step 2. DMSO RTI1.3NG Version 6 (for HLATest.exe)

Step 3. MAK VRLink version 3.7.1 (for HLATest.exe)

In the TAMSS_ERSTA system for Experiment #3, Vega application Version 3.7.1 is installed on Hagrid, upon which CDTV was developed. DMSO RTI1.3NG Version 6 and MAK VRLink version 3.7.1 are installed on Hagrid, upon which HLATest was developed.

2.2.3 Environment

Perform the following additions/modifications on the computer operating system environment on Hagrid:

Step 1. Variable: Path (Addition)
Value: c:\ProgramFiles\DMSO\rti1.3ng-v6\win2000-vc6\bin;c:\mak\vrlink3.7.1-ngc\bin

Step 2. Variable: RTI_BUILD_TYPE
Value: Win2000-vc6

Step 3. Variable: RTI_HOME
Value: c:\Program Files\DMSO\rti1.3ng-v6

Step 4. Variable: MAK_RTIDIR
Value: c:\Program Files\DMSO\RTI1.3ng-v6\win2000-vc6

Step 5. Variable: MAK_VRLDIR
Value: c:\mak\vrlink3.7.1-ngc

Hagrid has the above settings on the system environment.

3 OPERATION

3.1 Startup

Follow the "Start-up Procedure for the ERSTA Mock-up" in Appendix A.

If one or more processes are not available, a message will appear in the command window. The TAMSS rapid prototype application should continue with whatever processes are still available, but functionality for failed or missing processes will be unavailable.

3.2 Hand Controller

The hand controller for the cabin operator is a bilateral handgrip, usable with either hand, and mounted on a joystick. The hand controller for the prototype carries a force isometric control thumb controller, several switches, and two triggers on the back. Appendix C “ERSTA Hand Controllers” describes the buttons and functions on the Hand Controller.

3.3 Game Pad

The game pad for the cockpit operator is a vibration feedback game pad. It is convenient for the operator to manipulate it on his/her laptop computer. It has two analog sticks, one eight-direction button (used as four-way for TAMSS_SA), nine program buttons (seven on the top and two on the side) and one slider. Appendix C “ERSTA Hand Controllers” describes the buttons and functions on the Game Pad.

3.4 Map Buttons

There are nine buttons associated with the moving maps, and they are distributed in five columns and two rows. The following list describes each button and its functionality. The buttons are listed in order starting with the right-most column and moving to the left-most column.

- OUT – Zoom In on the map.
- IN – Zoom Out of the map.
- ACO – Hide/Show Airspace Coordination Order (**ACO**) overlays.
- TAC – Hide/Show Tactical overlays.
- ALL – Hide/Show All overlays.
- OWN – Hide/Show Ownship overlay and sensor footprint.
- CLR – Return Autoslew position to default (i.e. Clear operator designated autoslew position).
- DT – Hide/Show designated target overlays.
- NOR – Indicates current map orientation (North up). In Experiment #3, this button will toggle the map orientation between North Up (NOR) and Heading up (HDG).
- GRD – Turn ON/OFF the map grid.

3.5 Shutdown Procedure

Follow the "Shutdown Procedure for the ERSTA Mock-up" in Appendix A.

4 CUSTOM DATABASE

The database has two parts: visual simulation and map. The visual simulation database includes all the 3-D scene databases and the 3-D flight models. The map database includes 2-D maps, Airspace Coordination Order data and 2-D symbologies.

4.1 Add a New Flight Model

Add a new flight model as follows:

Step 1. Add the new flight model, including the Open Flight file (.flt), Texture files (.rgb) and the Texture attribute file (.attr), to the GoodEntity folder.

Step 2. Give a name to the model, ensuring that the name is consistent with other files (Refer to “The Structure of the Model Map Files” in Appendix C).

Step 3. Add the model in the GagetownN.adf (N:1-4 based on the scenario) follow the VEGA Lynx User’s Guide” [Ref 3].

Step 4. Make sure all the related files have been updated with the new flight model.

4.2 Modify an ACO Overlay

Modifying an ACO overlay (i.e. area, flight plan, line, symbol or label) is achieved through modification of the corresponding aco_x.xml file (i.e. aco_1.xml, aco_2.xml, etc.). An area is defined by three or more points, which correspond to each “corner” of the specified area. A flight plan is described by one or more locations (i.e. waypoints). Each line is defined by two or more points (i.e. locations) which are connected together when drawn. Each overlay symbol is described by its image (what the operator will see on the map) and location (where the symbol is drawn on the map). Similarly, each label is described by a text string (that which is to be displayed on the map) and location.

4.2.1 Modifying an Area

To modify an existing area:

Step 1. Locate the corresponding <AREA></AREA> pair in the .xml file.

Step 2. Change the location of a corner on the map by updating the numbers between the <LOCATION> and </LOCATION> tags for that given corner.

These three numbers represent the X, Y, and Z values of the corner in UTM co-ordinates.

Step 3. Remove an existing corner by deleting the corresponding <LOCATION></LOCATION> tags and everything between them.

Step 4. Add a new corner by inserting a new <LOCATION></LOCATION> pair within the corresponding area and specifying the X, Y, and Z values as described above.

WARNING: The order in which corners are specified is important. Specify each corner in the order you would encounter them if walking clockwise or counter clockwise around the entire perimeter of the area being defined. Failure to do so may cause the area to be drawn incorrectly.

4.2.2 Modifying a Flight Plan

To modify an existing flight plan:

Step 1. Locate the corresponding <FLIGHTPLAN></FLIGHTPLAN > pair in the .xml file.

Step 2. Change the location of a waypoint on the map by updating the numbers between the <LOCATION> and </LOCATION> tags for that given waypoint.

These three numbers represent the X, Y, and Z values of the corner in UTM coordinates.

Step 3. Remove an existing waypoint by deleting the corresponding <LOCATION></LOCATION> tags and everything between them.

Step 4. Add a new waypoint by inserting a new <LOCATION></LOCATION> pair within the corresponding flight plan and specifying the X, Y, and Z values as described above.

4.2.3 Modifying a Line

To modify an existing line:

Step 1. Locate the corresponding <LINE></LINE > pair in the .xml file.

Step 2. Change the location of a line point by updating the numbers between the <LOCATION> and </LOCATION> tags for that given point.

These three numbers represent the X, Y, and Z values of that point in UTM coordinates.

Step 3. Remove an existing line point by deleting the corresponding <LOCATION></LOCATION> tags and everything between them.

Step 4. Add a new line point by inserting a new <LOCATION></LOCATION> pair within the corresponding line and specifying the X, Y, and Z values as described above.

4.2.4 Modifying a Symbol

To modify an existing symbol:

Step 1. Locate the corresponding <SYMBOL></SYMBOL> pair in the .xml file.

Step 2. Display a different image on the map by updating the file name that precedes the end tag </IMAGE>.

Step 3. Change the location of the symbol on the map by updating the numbers between the <LOCATION> and </LOCATION> tags.

These three numbers represent the X, Y, and Z values of the symbol in UTM coordinates.

4.2.5 Modifying a Label

To modify an existing label:

Step 1. Locate the corresponding <LABEL></LABEL> pair in the .xml file.

Step 2. Change the text string being displayed on the map by updating the text string between the <TEXT></TEXT> tags.

Step 3. Change the location of the text string on the map by updating the numbers between the <LOCATION> and </LOCATION> tags.

These three numbers represent the X, Y, and Z values of the label in UTM co-ordinates.

4.2.6 Adding a New Area or Deleting an Existing Area

To add a new area:

Step 1. Insert a new <AREA></AREA> pair between the <OVERLAY> and </OVERLAY> tags (outside of any existing <AREA></AREA>, <FLIGHTPLAN></FLIGHTPLAN>, <LINE></LINE>, <LABEL></LABEL> and <SYMBOL></SYMBOL> pairs).

Step 2. Define at least three corners and specify the corresponding LOCATION data as described above.

To delete an existing area, delete the corresponding <AREA></AREA> tags and everything between them.

4.2.7 Adding a New Flight Plan or Deleting an Existing Flight Plan

To add a new flight plan:

Step 1. Insert a new <FLIGHTPLAN></FLIGHTPLAN> pair between the <OVERLAY> and </OVERLAY> tags (outside of any existing <AREA></AREA>, <FLIGHTPLAN></FLIGHTPLAN>, <LINE></LINE>, <LABEL></LABEL> and <SYMBOL></SYMBOL> pairs).

Step 2. Define at least one waypoint and specify the corresponding LOCATION data as described above.

To delete an existing flight plan, delete the corresponding <FLIGHTPLAN></FLIGHTPLAN> tags and everything between them.

4.2.8 Adding a New Line or Deleting and Existing Line

To add a new line:

Step 1. Insert a new <LINE></LINE> pair between the <OVERLAY> and </OVERLAY> tags (outside of any existing <AREA></AREA>, <FLIGHTPLAN></FLIGHTPLAN>, <LINE></LINE>, <LABEL></LABEL> and <SYMBOL></SYMBOL> pairs).

Step 2. Define at least two points and specify the corresponding LOCATION data as described above.

To delete an existing line, delete the corresponding <LINE></LINE> tags and everything between them.

4.2.9 Adding a New Symbol or Deleting an Existing Symbol

To add a new symbol:

Step 1. Insert a new <SYMBOL></SYMBOL> pair between the <OVERLAY> and </OVERLAY> tags (outside of any existing <AREA></AREA>, <FLIGHTPLAN></FLIGHTPLAN>, <LINE></LINE>, <LABEL></LABEL> and <SYMBOL></SYMBOL> pairs).

Step 2. Specify the corresponding IMAGE and LOCATION data as described above.

To delete an existing symbol, delete the corresponding <SYMBOL></SYMBOL> tags and everything between them.

4.2.10 Adding a New Label or Deleting and Existing Label

To add a new label:

Step 1. Insert a new <LABEL></LABEL> pair between the <OVERLAY> and </OVERLAY> tags (outside of any existing <AREA></AREA>, <FLIGHTPLAN></FLIGHTPLAN>, <LINE></LINE>, <LABEL></LABEL> and <SYMBOL></SYMBOL> pairs).

Step 2. Specify the corresponding TEXT and LOCATION data as described above.

To delete an existing label, delete the corresponding <LABEL></LABEL> tags and everything between them.

4.3 Modify a Tactical Overlay

Modifying a tactical overlay (i.e. symbol or label) is achieved through modification of the corresponding tactical_N.xml file (N:1-4 – i.e. tactical _1.xml, tactical _2.xml, etc.). Each overlay symbol is described by its image (what the operator will see on the map) and location (where the symbol is drawn on the map). Similarly, each label is described by a text string (that which is to be displayed on the map) and location.

4.3.1 Modifying an Existing Symbol

To modify an existing symbol:

Step 1. Locate the corresponding <SYMBOL></SYMBOL> pair in the .xml file.

Step 2. Display a different image on the map by updating the file name that precedes the end tag </IMAGE>. To change the location of the symbol on the map, update the numbers between the <LOCATION> and </LOCATION> tags.

These three numbers represent the X, Y, and Z values of the symbol in UTM co-ordinates.

4.3.2 Modifying an Existing Label

To modify an existing label:

Step 1. Locate the corresponding <LABEL></LABEL> pair in the .xml file.

Step 2. Change the text string being displayed on the map by updating the text string between the <TEXT></TEXT> tags.

Step 3. Change the location of the text string on the map by updating the numbers between the <LOCATION> and </LOCATION> tags.

These three numbers represent the X, Y, and Z values of the label in UTM co-ordinates.

4.3.3 Adding a New Symbol or Deleting an Existing Symbol

To add a new symbol:

Step 1. Insert a new <SYMBOL></SYMBOL> pair between the <OVERLAY> and </OVERLAY> tags (outside of any existing <LABEL></LABEL> and <SYMBOL></SYMBOL> pairs).

Step 2. Specify the corresponding IMAGE and LOCATION data as described above.

To delete an existing symbol, delete the corresponding <SYMBOL></SYMBOL> tags and everything between them.

4.3.4 Adding a New Label or Deleting an Existing Symbol

To add a new label:

Step 1. Insert a new <LABEL></LABEL> pair between the <OVERLAY> and </OVERLAY> tags (outside of any existing <LABEL></LABEL> and <SYMBOL></SYMBOL> pairs).

Step 2. Specify the corresponding TEXT and LOCATION data as described above.

To delete an existing label, delete the corresponding <LABEL></LABEL> tags and everything between them.

5 REFERENCED DOCUMENTS

1. Modelling And Simulation Architecture Specification, CMC Document Part Number 409-A64025-001, Version 001, 10 January 2003.

2. CH146 Griffon ERSTA System Requirements Specification. Draft Rev 2, DND, 29 November 2001.

3. Vega Lynx User's Guide, Version 3.5, MultiGen Paradiam, August 2000.

4. Gagetown1.adf, Humf:\HFE Lab\Projects\Tamss_sa\Requirements.

5. Dis_eg_type, Humf:\HFE Lab\Projects\Tamss_sa\Requirements

6. Entity.map, Humf:\HFE Lab\Projects\Tamss_sa\Requirements.

6 ACRONYMS AND ABBREVIATIONS

ACO	Airspace Coordination Order
ARP	Aircraft Reference Position
CAS	Close Air Support
CDTV	Colour Day TeleVision
ERSTA	Electro-Optic Reconnaissance, Surveillance and Target Acquisition
GUI	Graphical User Interface
HLA	High Level Architecture
I/O	Input/Output
NTS	Networked Tactical Simulator
OTW	Out-the-Window
RTI	Run Time Infrastructure
SA	Situational Awareness
TAMSS	Tactical Aviation Mission System Simulation
TDP	Technology Demonstration Project
TI	Thermal Imager
UDP	User Datagram Protocol
UTM	Universal Transverse Mercator
XML	Extensible Markup Language

ANNEX A

START-UP PROCEDURE FOR THE ERSTA MOCK-UP (EXPERIMENT #3)

APPENDIX A – START-UP PROCEDURE FOR THE ERSTA MOCK-UP (EXPERIMENT #3)

This section describes the ERSTA Mock-Up equipment and processes, how to prepare the equipment and start the applications required to perform Experiment #3, and how to stop the applications and shut down the system.

A.1 Overview

The ERSTA Mock-Up has a total of thirteen processes running on the three computers as shown in Table A-1:

Table A-1: Processes and Computers for ERSTA

Computer	Process
Harry	• Sensor: Sensor Simulation • CDTV_Video.exe: Grabs CDTV Video Signal from Hagrid • ERSTAForms.exe: ERSTA Forms • Map.exe: Tactical Map • Launcher.exe: Listening to start the processes on Harry • Manager.exe: Start the ERSTA Simulation
Hagrid	• CDTV.exe: CDTV Video simulation • HLAtest.exe: HLA • runlm.exe: Run VR_LINK License Manager for HLA • lmdown.exe: Shutdown VR_LINK License Manager • Launcher.exe: Listening to start the processes on Hagrid
Hermione	• Map.exe: Cockpit Map • Launcher.exe: Listening to start the processes on Hermione

A.2 Preparing and Starting Up the Equipment

Step 1. Verify the joystick and game pad connection.

– Make sure the joystick is connected to the COM2 port on Harry.

– Make sure the game pad is connected to one of the USB ports on Harry.

Step 2. Verify the network connections

- There should be four network cables connected to the hub: one from the NTS network hub and the other three from the network cards on Harry, Hagrid and Hermione.
- Verfiy that the indicate lights on the hub for these four connections are bright and flashing.

Step 3. Verify that the video connections are as follows:

- The splitter input is connected to the S-Video output on Hagrid.
- One splitter output is connected to the ATI video card input on Harry.
- The other splitter output is connected to the ATI video card input on Hermione.

Step 4. Turn on the three computers in the following order: Harry, Hermione, Hagrid

Note: To ensure that the TV Channel stays ON on Hagrid for the video capture, Hagrid must start after Harry and Hermione.

Step 5. Log in to all the computers as “Exp3” (no password).

The Launcher.exe has been added to the start menu. It will be started automatically once the computers have been logged in to as “Exp3”. A command window will appear and will stop printing at “Listening…”

Note: If the Launcher command window is closed by mistake, double-click on the “Launcher” icon on the desktop of the computer to run it again.

Step 6. Verify the TV Channel and Display Resolution on Hagrid

- Make sure the TV channel on Hagrid is ON by verifying that the TV channel is highlighted in green under Control Panel->Display->Setting->Advanced-> Displays. If it is highlighted in red, click on the channel button on the left to make it green.
- The display resolution on Hagrid should be 640*480.

Note: To change the display resolution, go to Control Panel->Display->Settings, move the Screen area slider left<->right to the correct resolution.

Step 7. Verify the Rotation and Resolution of the Tactical Map Display on Harry

- The Tactical Map Display (right side display of the ERSTA station) must be in Landscape orientation. If it is not, right click anywhere on the background of the display and select “Rotate”.
- The resolution of the Tactical Map Display must be 1024*768.

Step 8. Verify the Rotation and Resolution of the Video Display on Harry

- The Video Display (left side display of the ERSTA station) must be in Portrait orientation. If not, right click on anywhere of the background of the display and select "Rotate".
- The resolution of the Video Display must be 768*1024 (shown as 1024*768 in display settings).

Step 9. Ensure that the resolution of the Cockpit Map Display on Hermione is 800*600

A.3 Starting the Applications

Step 1. Start the applications

- Click on the "runLm" icon on Hagrid and wait for a few moments until the following lines appear:

  "hvl2 dvl1 dvl2"

  "vl3"

  Note: This process only needs to be started once. It can be kept running until the experiments are finished.

Step 2. There are four icons on the desktop of Harry (S1, S2, S3, S4), which are used to start the four scenarios separately. Double-click on one of the four icons to start the corresponding scenario.

- Tactical Map will appear on the Tactical Display with overlays of the corresponding scenario.
- Cockpit Map will appear on the Cockpit Display with overlays of the corresponding scenario.
- The CDTV video image will appear at the top half part of the video display. The image starts as white and it takes about three to five minutes before the scene shows up.
- The same CDTV video image will also appear in the TV frame of the cockpit center display. The image starts as white and it takes about three to five minutes before the scene shows up.
- The CDTV video image should move with the joystick and game pad (to make sure the sensor is running).
- The CDTV video image should move with the OTW scene (to make sure HLA is running).
- The ERSTA form frame will appear at the bottom half part of the video display.
- Click the Target Mark button on the joystick or game pad. The contact form pops up within the form frame. Click on Cancel to make it disappear.

- On Hagrid, the VR_Link licenses must be checked out. The lines below will be printed out on the runLm Command window.

  "OUT : "hvl1" Exp3@Hagrid
  "OUT : "hvl2" Exp3@Hagrid

  Note: If the license is not checked out correctly, HLA will NOT run properly. Refer to the section below "Run and Shutdown the VR_Link License Manager" to solve the problem.

The ERSTA Mock-Up is now ready.

A.4 Shutting Down the Applications

Step 1. Stop the applications as follows:

- Make sure the Stage RTI is still running and is not frozen or paused.
- Press "q" on the keyboard on Hagrid (the command syntax is not case sensitive)

Step 2. Verify that all processes have been closed.

On Harry:

- Tactical Map window should be closed.
- Video Capture window should be closed.
- ERSTA Form window should be closed.
- In the Launcher command window, "Sensor has been closed!" should be displayed.

On Hagrid:

- CDTV window should be closed.
- In the Launcher command window, "HLA has been shut down!" should be displayed.
- The VR_link licenses should be checked back in. In the runLm command window, the lines below should be printed out.

  IN: "hvl1" Exp3@Hagrid"

  IN: "hvl2" Exp3@Hagrid"

  Note: If the above message is not printed out, the license is not checked back in, HLA can NOT restart properly. Refer to the section below "Run and Shutdown the VR_Link License Manager" to solve the problem.

On Hermione:

– Cockpit Map window should be closed.

The ERSTA system is now shut down and ready to restart.

A.5 Shutting Down the Applications Individually

If the ERSTA Mock-Up cannot be shut down properly as a result of errors that may have occurred while following the procedures described in "Stopping the Applications", all the processes included in the ERSTA Mock-Up must be shut down individually, as follows:

On Harry:

Step 1. Shut down Tactical Map by moving the mouse to the Tactical Map window and clicking on it to activate the Tactical Map window , then press the “Esc” key on the keyboard.

Step 2. Shut down Video Capture by moving the mouse to Video Capture window and clicking on it to activate the Video Capture window, then press the “Esc” key on the keyboard.

Step 3. Shut down ERSTA Forms by clicking on “SYSTEM” on the ERSTA Form menu (at bottom right), then clicking on “LOGOUT” from the dropdown menu.

Step 4. Shut down Sensor Simulation by closing the Launcher command window. To do this, click on the close icon (x) at the top-right side of the window.

Step 5. Rerun the launcher window by clicking the “Launcher” icon on the desktop to make it ready to restart ERSTA.

On Hagrid:

Step 1. Shut down CDTV and HLA by closing the Launcher command window. To do this, click on the close icon (x) at the top-right side of the window.

Step 2. Rerun the launcher window by clicking the “Launcher” icon on the desktop to make it ready to restart ERSTA.

Step 3. Verify that the VR_link license is checked back in by verifying that the following lines are displayed in the runLm command window:

IN: “hvl1” Exp3@Hagrid”

IN: “hvl2” Exp3@Hagrid”

If the lines are not displayed, refer to the section below “Run and Shutdown the VR_Link License Manager” to solve the problem.

On Hermione:

Step 1. Shut down the Cockpit Map by moving the mouse to Cockpit Map window and clicking on it to make the Cockpit Map window active.

Step 2. Press the "Esc" key on the keyboard.

A.6 Run and Shut Down VR_Link License Manager

The VR_Link license is installed to run HLA. When the ERSTA system starts up, the license will be checked out, and when the ERSTA system shuts down, the license will be checked back in so that it can be reused again.

If the license does not check out and check in correctly, HLA will not run properly.

Step 1. Run VR_Link License

- Click runLm on the desktop to activate the runLm command window. It takes about one minute to make the license ready and for the following lines to be displayed.

  "hvl2 dvl1 dvl2"

  "vl3"

Step 2. VR_Link License Check Out

Step 3. When the ERSTA system (HLA) is started, the license will be checked out. After a few minutes, the following lines are displayed:

OUT: "hvl1" Exp3@Hagrid"

OUT: "hvl2" Exp3@Hagrid"

If these lines are not displayed, verify / perform the following:

- Make sure Stage RTI is running properly without being frozen, paused or shut down.
- Shut down ERSTA individually (refer to Shutting Down the Applications Individually).
- Close the runLm command window (refer to Forcing the License Manager (LM) to Close).
- Restart ERSTA (refer to Starting the Applications).

Step 4. VR_Link License Check In

When the ERAST system (HLA) is shut down, the license will be checked back in. After a few minutes, the following lines are displayed:

IN: “hvl1” Exp3@Hagrid”

IN: “hvl2” Exp3@Hagrid”

If these lines are not displayed, verify that the Stage RTI is running properly without being frozen, paused or shut down.

Step 5. Forcing the License Manager (LM) check back in:

Close the Launcher Command window to force HLA process shut down. Doing this will make the VR_link license checked back in. Make sure to rerun the launcher window by clicking the “Launcher” icon on the desktop to make it ready to restart ERSTA.

Step 6. Forcing the License Manager (LM) to Close:

Run “lmdown” on the desktop. Doing this will force the license to check back in and the “runlm” command window to close. Make sure to rerun the the license manager by clicking the “runlm” icon on the desktop to make it ready to restart ERSTA.

APPENDIX B

THE STRUCTURE OF THE MODEL MAP FILES FOR SCENARIO SETUP

APPENDIX B – THE STRUCTURE OF THE MODEL MAP FILES FOR SCENARIO SETUP

Figure B-1 shows the structure of the model map files on both NTS and ERSTA side.

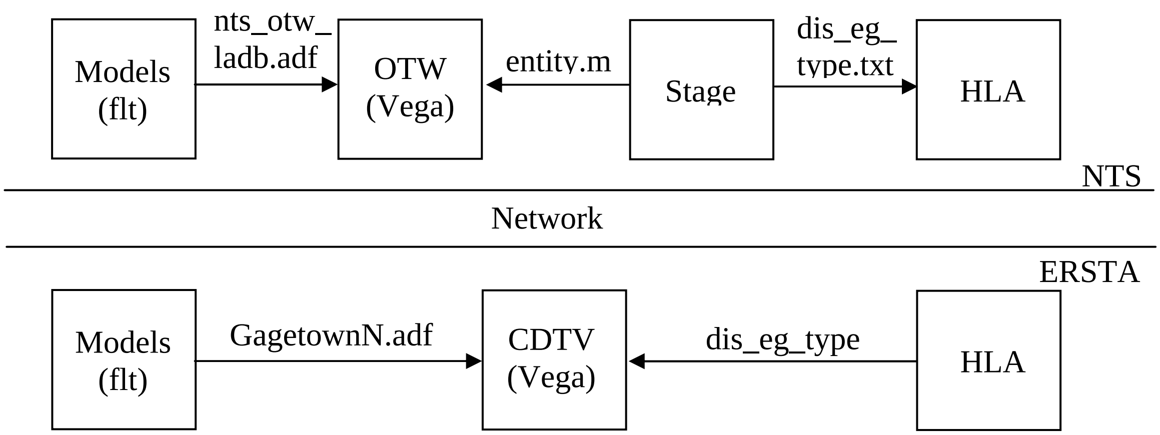

Figure B-1 Structure of the Model Map Files

There are a total of five files on map entities for the NTS and ERSTA applications. The file names, locations and functions are described in Table B-1.

Table B-1 Model Map File Names, Locations, Functions, Formats and Examples

File Name	Location	Function	Format	Example
nts_otw_ladb.adf	CURSE-EOS-> N:\data\ADF\	Application Define File used by Out The Window (OTW) application nts_otw.exe) to set up the system variables including the paths to access the FLT format models	Set up through Lynx (Graphic User Interface of Vega)	[Ref 4]
entity.map	CURSE-EOS-> C:\tamss_rt\data\hla\ini\	Entity map file to map entity names between STAGE (tamss_stage_sim.exe) and OTW (nts_otw.exe)	STAGE name is on the left and the Vega name is on the right.	[Ref 5]

dis_eg_type.txt	CURSE-EOS-> C:\vpi\stage400 \data\	Distribute Type File to define the entity names. Used by Stage (tamss_stage_sim.exe) and HLA (tamss_stage_de.exe) in the NTS side.	There are six columns. Refer to Example file for the definition. DIS Type (the first column) needs to be unique for each entity.	[Ref 6]
Gagetown1.adf Gagetown2.adf Gagetown3.adf Gagetown4.adf	Hagrid-> C:\TAMSS\Experiment3\Project\Process\SysMag\Launcher\	Application Define File used by CDTV video image application (CDTV.exe) to set up the system variables including the paths to access the FLT format models	Set up through Lynx (Graphic User Interface of Vega)	[Ref 4]
dis_eg_type	Hagrid-> C:\TAMSS\Experiment3\Project\Process\SysMag\Lanucher\	Distribute Type File to define the entity names. Used by CDTV (CDTV.exe) and HLA (tamss_stage_de.exe) on the ERSTA side	Should be the same file as dis_eg_type.txt on the NTS side. Note: No extension name (.txt) in the ERSTA side.	[Ref 6]

Table B-2 shows the entities and scene tiles for the four Scenarios. The consistency of the entity names is important. The names are case sensitive. The five files listed in the Table B-1 must use exactly the same entity names provided in Table B-2.

Table B-2 Entity Names and Scene Tiles for the Scenarios

Item	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Models	M113_APC	MIA2_Abra	M110_SPH	M1045_Tow
	AH_64	M939A2	MI-28_Havoc	SU-25_Frogfoot
	BMP-2	BRDM-2-AT-5 (BTR_80)	T-72	ZSU-23-4
	M1025_Hum_Tow	M1025_Hum_Tow	M1025_Hum_Tow	M1025_Hum_Tow
	M109	M109	M270_MLRS	M270_MLRS
	Tents	Tents	Tents	Tents
	M2A3_Brad	M2A3_Brad	Hum_Avenger	M2A3_Brad
	Hum_Avenger			Hum_Avenger
	CH146	M113_APC		
	AH64_ Crashed			
Scene	Gagetown 0_1	Gagetown 1_1	Gagetown 2_0	Gagetown 0_2
	Gagetown 0_2	Gagetown 1_2	Gagetown 2_1	Gagetown 0_3
	Gagetown 1_1	Gagetown 1_3	Gagetown 2_2	Gagetown 0_4

Item	Scenario 1	Scenario 2	Scenario 3	Scenario 4
	Gagetown 1_2	Gagetown 2_1	Gagetown 3_0	Gagetown 1_2
	Gagetown 2_1	Gagetown 2_2	Gagetown 3_1	Gagetown 1_3
	Gagetown 2_2	Gagetown 2_3	Gagetown 3_2	Gagetown 1_4

APPENDIX C

ERSTA HAND CONTROLLERS

APPENDIX C – ERSTA HAND CONTROLLERS

C.1 Joystick

Figure C-1 illustrates the switch definition of the Joystick and button functions that are defined in Table C-1. The four-way button on the right side is reserved for TI sensor control, which is not available for Experiment #3.

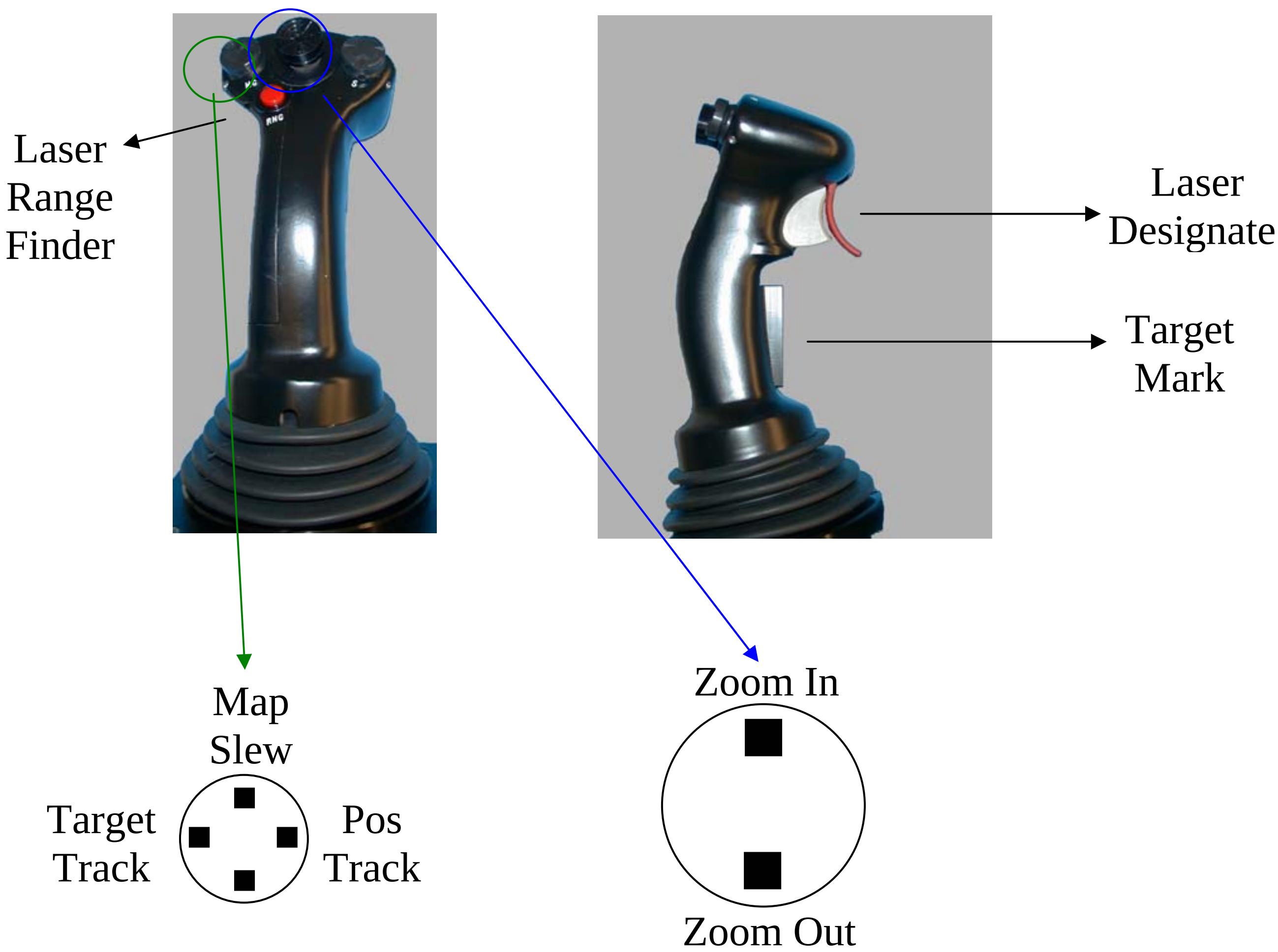

Figure C-1 ERSTA Joystick

C.2 Wing Man Game Pad

Figure C-2 illustrates the switch definition of the Wing Man Game Pad and button functions that are defined in Table C-1.

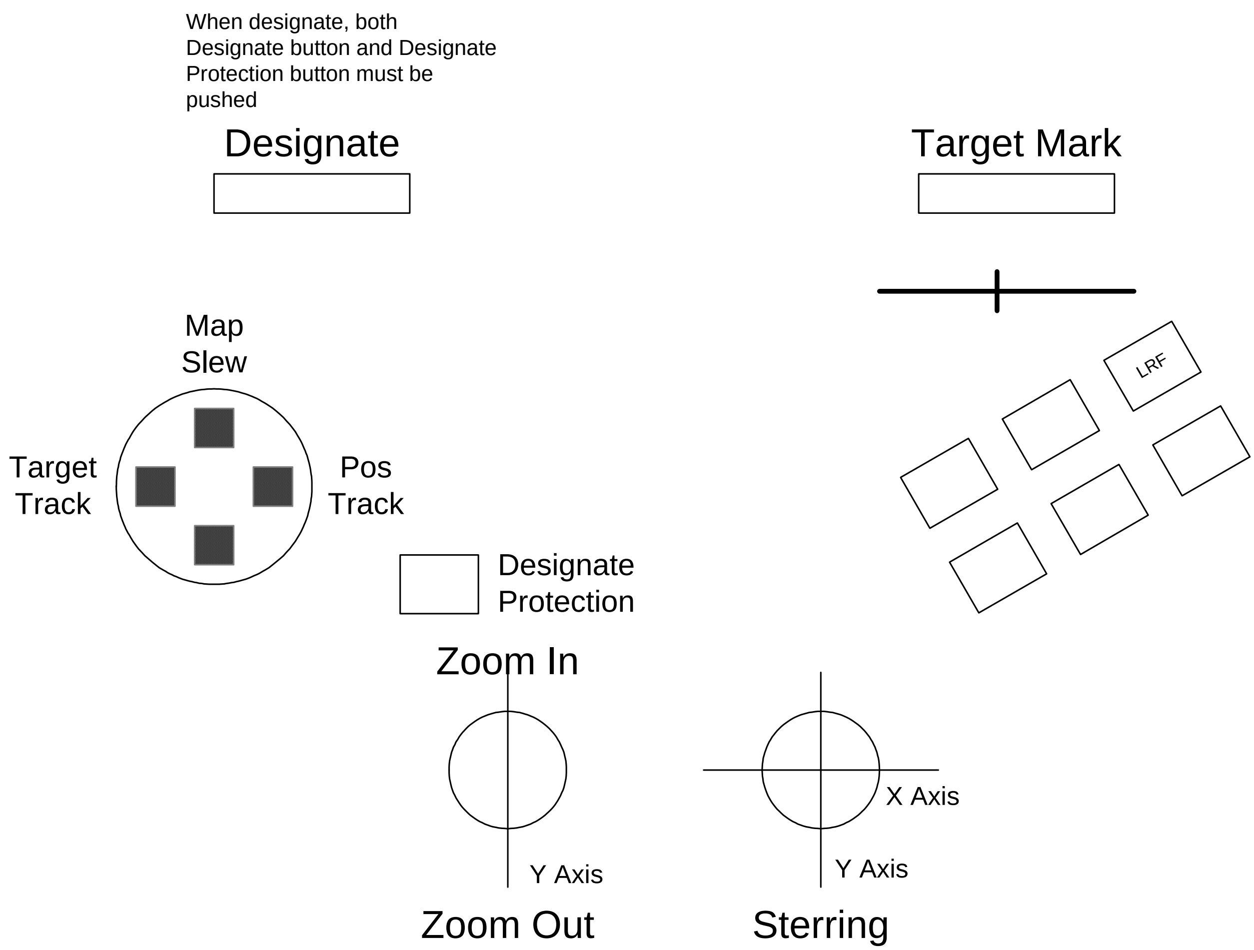

Figure C-2 ERSTA Wing Man Game Pad

Table C-1 Hand Controller and Button Functions

Function	Type	Location	Description
Map Slew	Momentary Switch	Joystick, Left, 4 position button, Up	The button commands the sensor slew to the position designated on either the tactical map or cockpit map. If there is no position designated on the map, the sensor slews to the default auto-slew position pointing to the nose (pan zero/ tilt zero) of the aircraft. Slew will start once the button is pressed and stop when the sensor reaches the designated position or within five seconds, whichever comes first.
Target Track	Momentary Switch	Joystick, Left, 4 position button, Left	The button commands the sensor to track a dynamic object within the track window. The target auto-track starts when the button is pressed and stops when the joystick is moved from the zero position on either the X or Y axis.
Position Track	Momentary Switch	Joystick, Left, 4 position button, Right	The button commands the sensor to track a still object or position at the centre of the window. The position auto-track starts when the button is pressed and stops when the joystick is moved from the zero position on either the X or Y axis.
Zoom in	Momentary Switch	Joystick, Middle, 4 position button, Up	When the button is pressed the zoom factor increases. Holding the button provides continuous zoom to the system's maximum zoom (20)
Zoom in	Momentary Switch	Joystick, Middle, 4 position button, Down	When this button is pressed, the zoom factor decreases. Holding the button provides continuous zoom to the system's minimum zoom (1)
Laser Range Finder (LRF)	Momentary Switch	Joystick, Front, red button	Pressing and releasing the button toggles the Laser Range Finder OFF and ON. The default LRF is ON; that is, LRF is ON when the system starts.
Laser Designate Firing (LDF)	Momentary Switch	Joystick, Back, up with guarded bar	Pressing the trigger starts the Laser Designate Firing (LDF). Holding the trigger continues the operation of the LDF and releasing the trigger stops the LDF.

Function	Type	Location	Description
Target Mark	Momentary Switch	Joystick, Back, down	Pressing the trigger results in a Contact Form popping up on the bottom half of the visual simulation display. Once the form is sent, the target position is marked on the map. The trigger also starts position auto-track. The auto-track stops if a "Cancel" button on the form is clicked or if the joystick is moved from the zero position on either X or Y axis.

C.3 Cockpit and Cabin Hand Controller Design

Criteria for the Current Turret Controller is as follows:

- The first operator to deflect his turret steering control from its centre (dead-zone) position will become the Current Turret Controller. Once the Current Turret Controller is established, the other operator will not have access to steering and mode buttons (Slew, position auto-track and target auto-track). Refer to Table 1. However, the other operator will still have access to the button controls for non-turret related functions. As soon as the Current Turret Controller lets the joystick return to its centre position, both operators have access again.
- The first operator to select a mode button will become the Current Turret Controller as long as that mode is still active.
- The CDTV zoom control will work in the same way. The first operator to press the zoom button will became the Current Zoom Controller. Once the Current Zoom Controller is controlling the zoom, the other operator cannot control the zoom anymore until the Current Zoom Controller releases the zoom button and it returns to its centre position.
- The Current Turret Controller and the Current Zoom Controller could be different operators.

- When the map is clicked and the target position field on the CAS form does not have focus, the map click will set the map-slew position. There is one map-slew position stored for each map; they are independent of one another. When the slew button is pressed, the turret will slew to the map position associated with the operator; that is, if the Cockpit Operator clicked a position on the Cockpit Map, the turret only slews to that position if the Cockpit Operator presses the slew button. If the Cabin Operator presses the slew button, then turret will only slew to the position on Tactical Map he selected. If the Cockpit Operator selects position on the Cockpit Map and the Cabin Operator selects nothing, when the Cockpit operator presses the slew button on the Cockpit joystick, the turret will slew to the selected position on the Cockpit Map. When the Cabin Operator presses the slew button on the Cabin joystick, the turret will slew to the default slew position, pointing to the nose of the aircraft.

Annex C – CSE Framework (Published Paper)

Proceedings of the *International Symposium on Aviation Psychology, 12*, April 2003.

CACR

COGNITIVE SYSTEMS ENGINEERING (CSE) FRAMEWORK FOR EVALUATING NEW COCKPIT INTERFACES

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With an increased role of modeling and simulation new cockpit technologies can be thoroughly evaluated before being implemented in an aircraft. This process of evaluation, however, needs to be guided by a framework based on our knowledge of the strengths and limitations of the human operator. Situation awareness (SA) has become the dominant construct used in evaluating new technology. However, it is unlikely that a single construct accurately captures the complexity of the cognitive processes under study. Rather than using a single construct we propose a cognitive systems engineering (CSE) framework for guiding the modeling and simulation process in evaluating new cockpit technologies. The CSE framework uses converging measures of three central constructs (i.e., SA, workload, and task-relevant performance) to operationalize the relevant cognitive processes underlying the pilot-machine interaction. It is argued that converging measures of these central constructs are essential for providing a comprehensive perspective on the impact of new interfaces on the pilot and the crew.

Introduction

In the past, the implications of pilot-machine interactions were rarely explored thoroughly when new technology was added to existing systems. With the development of affordable simulation environments, however, the feasibility of testing new technologies before they are installed in aircraft has increased substantially. Savings in terms of human costs and technology retrofits are potentially enormous. Furthermore, there have been recent advances in both our knowledge of human psychology and the capabilities of simulation environments, thus supporting a greater role for modeling and simulation. However, it is important that the evaluation process of modeling and simulation be guided by a proper operationalization of the cognitive processes under study.

It has proven difficult to properly define the relevant cognitive processes for empirical evaluation of the pilot-machine interface. One approach to this problem is for researchers to focus on a single construct that captures a substantial and/or relevant portion of the pilots' performance. The construct of situation awareness (SA) has been used in this way, both in the aviation field and more broadly when researchers have explored the relations between technology and human performance. SA refers to the pilots' conscious comprehension of the environment and their ability to project future scenarios (Endsley, 1995a, 2000). Hence, SA is most commonly measured with various questionnaires whereby pilots either subjectively evaluate their SA or the reported knowledge of the pilot is compared to the actual state of the system and the environment (Endsley, 1995b; Pew, 2000). Less commonly, SA is also evaluated by measuring task-relevant performance, which is assumed to give an indirect indication of pilots' comprehension of the situation (Vidulich, 2000). Subjective and objective measures are rarely used together to evaluate the impact of new technology on the pilot or the crew.

Measuring SA has provided some important insight into the impact that a new technology may have on pilots' comprehension of a system and their ability to selectively process relevant information. However, the pilot-machine interaction depends on a complex, dynamic model of the system and the situation that includes much more than selective attention and comprehension. For example, a pilot's ability to interact with a system is also highly dependent on perceptuomotor coordination and action planning. It is therefore unlikely that a single construct can sufficiently capture the behavioural variance produced by the complex pilot-machine interaction. Furthermore, a single construct is unable to effectively represent cognitive processes that underlie pilot-machine interactions.
It is important that the constructs that are chosen to evaluate the pilot-machine interaction be

comprehensively operationalized. Using a single operation seriously limits the nature and the meaning of the phenomena under study (Gardner, Hake and Eriksen, 1956). Due to the complexity of the pilot-machine interaction and the underlying cognitive processes, it is unlikely that a single measure will provide sufficient information to allow for a general conclusion as to how a new technology affects the pilot or the crew. Therefore, in order to properly operationalize the chosen constructs, multiple operations or measures should be used.

In the present paper we propose a cognitive systems engineering (CSE) framework for guiding the modeling and simulation process in evaluating new cockpit technologies. The CSE framework uses converging measures of three central constructs (i.e., SA, workload, and task-relevant performance) to operationalize the relevant cognitive processes under study. We argue that converging measures of these central constructs are essential for providing a comprehensive perspective on how new interfaces influence pilots' responses in the cockpit.

The CSE framework

As shown in Figure 1, the CSE framework includes a theoretical construct, the dynamic mental model, and three empirical (i.e., measurable) constructs: situation awareness, workload, and task-relevant performance. Our review of the literature indicated that these three empirical constructs capture a significant amount of the variance in the pilot-machine interface.

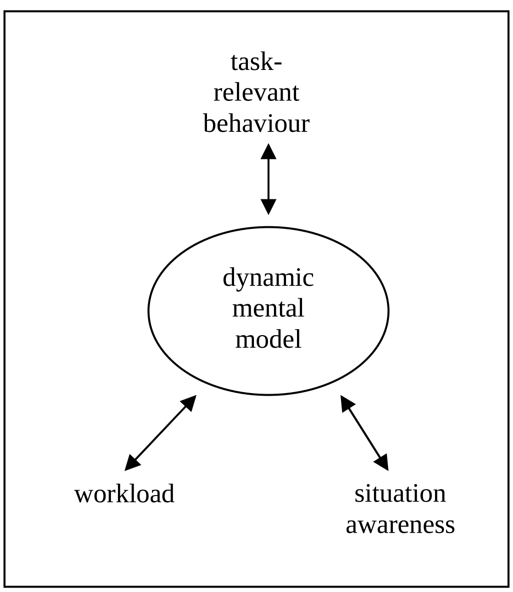

Figure 1.

The proximal goal of the CSE framework is to provide a context within which to interpret the dependent variables that are assessed in a modeling and simulation evaluation. The CSE framework is not intended to represent a complete model either of the human operator or of the situation, although further developments of the framework will be designed to expand the theoretical and predictive power of the model.

The central theoretical construct in the CSE framework is the dynamic mental model. It captures the notion that the human operator constantly creates and maintains an internal representation of the ongoing situation. When experimental methods are used to measure performance in an evaluation of new technology, all of the measurements indirectly index the pilot's dynamic mental model. The three empirical constructs provide a comprehensive (although not exhaustive) assessment of the dynamic mental model. Workload indexes the cognitive effort required by the pilot, SA captures the pilot's perception of events and his integration of those events into a coherent understanding of the situation, and task-relevant performance captures the behaviors associated with the interactions between the pilot (or crew) and the machine.

SA is an empirical construct in the CSE framework that can be defined simply as "knowing what is going on around you" (Endsley, 2000, p. 5). The term was originally used to capture why some fighter pilots were more successful (and therefore lived longer) than others (Spick, 1988). SA is closely tied to knowing how to distinguish important information in the environment from less important information (selective attention), as well as the ability to quickly comprehend and predict the importance of changes to elements in the environment (Adams, Tenney and Pew, 1995; Durso and Gronlund, 1999; Endsley, 1995a; 2000; Sarter and Wood, 1995).

Measuring SA provides important insight into how well the pilot comprehends a system's functionality and how well the pilot is able to integrate the information presented on the instrumentation into a coherent picture of the system and the environment.

The second empirical construct that forms the core of the CSE framework is workload. Workload is an important construct in aviation and other complex cognitive tasks because humans are limited in their ability to process information and to respond appropriately (Hancock and Desmond, 2001). A helicopter pilot on a search-and-rescue mission who is flying with night vision goggles near the ground during a rain storm is likely to be in a situation of heavy workload. A large amount of rapidly changing information has to be monitored and the pilot must constantly update his or her dynamic mental model of the environment. In contrast, a pilot flying a routine transit leg in good weather is probably in a low workload situation.

Workload has proven to be a very useful construct for understanding changes in pilots' behaviour under different situational demands and constraints (Flach and Kuperman, 2001; Wickens, 2001). Technology "improvements" should hypothetically decrease workload, but in practice, a technology that adds information to the pilot's environment and/or requires the pilot to perform additional tasks may actually increase workload, at least in the short term (Vidulich, 2000). Thus, measuring changes in workload as a function of technology changes is crucial to understanding how technology influences pilots' performance.

The third empirical construct in the CSE framework, task-relevant performance, refers to the actions of the pilot or the crew (in relation to mission demands) that are potentially affected by the new technology. Adding a new technology to the cockpit can affect pilots' performance in various ways. For example, the addition of a new display screen to the F-18 cockpit that has enhanced information about approaching threats should improve pilots' ability to manoeuver in a threatening environment. However, other aspects of pilots' behaviour might be impaired or affected in ways that decreases their SA and/or interferes with how they interact with other systems. For example, adding the new display screen to the F-18 cockpit should result in the pilot spending time looking at that screen and interacting with it in certain ways. Concomitantly, the pilot may spend less time using other sources of information, or may use that information differently. Thus, defining and measuring task-relevant performance is an important aspect of understanding the impact of a new technology on performance in the cockpit.

A detailed discussion of the relations among SA, workload, and task-relevant behaviour is beyond the scope of the present paper. In brief, however, it is clear that both SA and workload represent outcomes that may not be directly realized in overt behaviour. Instead, we see these as a product of the pilot's creation and use of the dynamic mental model. Therefore, under some conditions, we would expect to find a high correlation between SA and workload. If, for example, a decrease in workload allows pilots to spend more time scanning the environment and detecting dangerous situations more quickly, then SA will increase as workload decreases. In our view, a complete disconnection between workload and SA would be evidence against the proposed framework since both constructs are assumed to be based on the pilots creating and updating their mental model.

Good SA does not always lead to good performance and high workload does not always predict poor performance. For example, highly trained pilots may function very well under high workload situations because of their extensive training and experience such that they continue to function effectively despite increased task demands. Nevertheless, we would predict that some other aspect of their performance (such as SA) might decrease under heavy cognitive demands. The CSE framework is based on the assumption that the three empirical constructs will typically be related such that, in many situations good SA (or low workload) will predict good performance. Hence, if task-relevant performance is operationalized appropriately as a specific and direct measurement of the behaviour that is likely to be affected by the technology change, then changes in task-relevant behaviour should be correlated with SA. On this view, if task-relevant behaviour becomes worse with new technology, then SA must necessarily decrease.

In summary, according to the CSE framework, the three experimental constructs (SA, workload, task-relevant performance) are second-order reflections of the pilot's dynamic mental model of the situation. Because it is impossible in practice to directly measure the contents of the dynamic mental model, defining performance relative to multiple constructs that access the mental model is likely to provide more useful information than focusing on a single construct.

In accord with the CSE framework, we propose that the evaluation of a new cockpit technology should include at least one, and preferably multiple measures of situation awareness, workload, and task-relevant performance respectively. Use of multiple measures will allow for a richer and more accurate answer to the question "how does the new technology affect the human-machine interaction"?

The value of multiple converging measures within the CSE framework

The pilot's internal model is a complex theoretical construct that is not directly measurable (as it is not possible to directly measure "memory" or "thinking"), and therefore the only measures we can use are behavioural in the sense that the pilot must perform some action that is then assessed. It is worth emphasizing, however, that unlike other cognitive constructs such as attention or working memory, the dynamic mental model represents a complex cognitive mechanism that incorporates various cognitive processes, such as selective attention, long-term memory and perceptuomotor coordination. Therefore it is unlikely that a single construct would capture the complexity of the dynamic mental model.

The approach taken when using the CSE framework is to evaluate the pilot-machine interaction and the underlying dynamic mental model by using the three central constructs of SA, workload and performance. These three central constructs are essentially behavioural in nature and separated from the theoretical construct of the dynamic mental model to avoid the risk of conceptual confusion where the defined measured behaviour is the same as the underlying cognitive mechanism (see for example, Flach, 1995). However, the three empirical constructs of SA, workload and performance must also be comprehensively represented through the use of multiple operations. This is because it is unlikely that any single measure can provide sufficient information to allow for general conclusions about the impact of a new technology on the user. Hence, in addition to assessing the three central constructs, we propose that researchers collect multiple measures for each construct.

An important distinction that is often overlooked in aviation research is between subjective and objective measures of constructs such as SA or workload. A subjective assessment, for example, of situation awareness requires that the pilot makes a judgment or provides an evaluation. Pilots might be asked to report on where they were looking during a manoeuver and what information they noticed. A researcher could objectively measure SA by measuring the pilots' head position as an index of where the pilot is attending. It is critical to distinguish between objective and subjective measures because an individual's perception of their behaviour or memory for a situation can be wrong. Subjective measures, for example, might be better characterized as *perceived* workload or *perceived* SA.

Subjective measures allow us to evaluate pilots' degree of comfort and acceptance of the new technology and as such can be extremely informative. For example, it is possible that adding a new cockpit system does not significantly affect pilots' performance. However, their level of acceptance and discomfort may increase significantly and later cause performance decrement. This is particularly true for high stress situations where workload is suddenly increased (Andre, 2001). Similarly, pilots may subjectively prefer a new system to existing system whereas their performance is being impaired by the new technology. Therefore, using both subjective and objective measures will provide a more comprehensive evaluation of the impact of new technology on the pilot-machine interaction.

In a recent study, we demonstrated the benefits of using multiple measures to evaluate the implementation of a direct voice input (DVI) system for controlling the on-board computer in the CH146 Griffon helicopter (Herdman et al., 2001; Lessard et al., 2001). In this study, heads-up time was identified as a key to enhancing SA. Increased heads-ups time should improve pilots' ability to detect and respond to events in the external scene. Heads-up time was measured by tracking the pilots' head position throughout simulated reconnaissance missions. Heads-up time in the DVI condition was compared to a standard manual input condition that was configured based on how the Griffon crew currently enters commands into the CDU. As predicted, heads-up time increased with DVI relative to the manual condition (by an impressive 42%), indicating that the technology change had at least one of the expected and desirable outcomes on pilots' behaviour.

However, it was recognized that introducing the DVI system to the Griffon cockpit has a variety of other potential effects. First, DVI had the potential to change the crew interactions in that the flying pilot now had the opportunity to control the on-board computer (i.e., the CDU), whereas in the manual input situation only the non-flying pilot can enter commands on the CDU. So the workload or performance of the flying pilot might also be affected by the new technology. Second, if looking at the CDU to manually enter commands was a workload-intensive activity for the non-flying pilot, then DVI might decrease his or her overall workload. Other aspects of the pilots' task performance, however, were unlikely to be affected in the types of missions that were flown.

Herdman et al. (2001) included objective measures to assess the workload demands of the DVI versus manual input systems. Objective workload was measured using detection of auditory and visual stimuli (i.e., targets) by both pilots. The targets (auditory tones or visual flashes in the external scene) were presented randomly in the course of the simulated missions. Pilots were instructed to respond as quickly as possible when they detected a target by pressing a key. Target detection as an index of workload has been used extensively and thus has both empirical and theoretical support. Essentially, the speed and accuracy with which pilots respond to the auditory and/or visual targets is used as a measure of their available attentional capacity.

Herdman et al. (2001) found that the workload of the non-flying pilots was less in the DVI condition than in the manual input condition. It was concluded, therefore that for the non-flying pilots, the DVI system should improve SA and lower workload. Interestingly, it was found that the workload of the flying pilots <u>increased</u> significantly in the DVI condition. This increase in workload occurred even though the flying pilots used the DVI capability infrequently (i.e., less than 1 minute DVI time per each 20 minute mission). Subjective measures of the flying pilot's workload and SA did not differ across the DVI versus manual input condition, however. These results support our contention that a broad assessment of multiple constructs is necessary to achieve a comprehensive understanding of the impact of a new technology.

The example from the DVI study emphasizes the importance of using converging measures to properly evaluate the impact of new technology on the pilot and the crew. Research using the CSE framework and the principles of broad assessment will test the usefulness of this approach. These techniques are not complicated to apply. For example, to assess the use of a new altimeter, altitude maintenance could be used as an index of the pilot's adherence to the flight plan (task-relevant behaviour), the simulation can be frozen and pilots could be asked to report altitude information (situation awareness). Their workload could be measured (using target detection) with the new and old instruments.

Systematic assessment of all three constructs with both subjective and objective indices would allow for a comprehensive picture of how the new technology influences the pilot-machine interaction. By including multiple measures of the three behavioural constructs a more complete picture can be inferred about the underlying cognitive processes.

In summary, the CSE framework encourages researchers to develop measures that assess pilots' behaviour from multiple perspectives. The framework brings different measures and different definitions of the pilot-machine interaction together in a single framework that will allow us to more thoroughly evaluate the implications of new cockpit technology for the pilot. The central assumption is that using converging measures of these three central constructs (i.e., SA, workload, and task-relevant performance), will provide a comprehensive perspective on how new interfaces influence pilots' responses in the cockpit.

Conclusions

The increasing complexity of the modern cockpit calls for the development of tools and methods that allows us to evaluate the impact of new cockpit technology on the pilot and the crew. However, such evaluation tools must be guided by a proper operationalization of the relevant cognitive processes. The present paper proposes a cognitive systems engineering (CSE) framework that uses converging measures of central constructs (SA, workload, and task relevant performance) to evaluate how the pilot-machine interaction is affected by new technology.

A central tenet of the CSE framework is that the pilot-machine interaction in the cockpit is too complex for a single construct to provide sufficient information to evaluate the impact of an interface on pilots' overall behaviour. By using converging measures of the three central constructs it is more likely that we are capturing the relevant cognitive processes we want to evaluate. Furthermore, by distinguishing among SA, workload, and task-relevant performance, and the underlying mental representation (the dynamic mental model), researchers can more clearly operationalize the concepts for empirical purposes.

In particular, the CSE framework proposes the use of both subjective and objective measures for each of the three empirical constructs of SA, workload and performance. This is because subjective and objective measures of the same construct can produce different outcomes. For example, individual's perception of their behaviour or memory for a situation can diverge considerably from their actual performance. It is argued within the CSE framework that using multiple operations of both subjective and objective measures will provide a more comprehensive operationalization of SA, workload and performance and as such will provide a more complete evaluation of how a new technology affects the pilot and the crew.

The CSE framework is expected to provide important support to the modelling and simulation process in evaluating new cockpit technology. Research that is conducted within the CSE framework should allow for comprehensive and valid assessment of human factors aspects of new aviation technology. Systematic application of the framework in the evaluation of new technology for the cockpit will allow researchers to evaluate the results of assessments produced by different labs under different conditions to be compared more easily.

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Annex D – Report 1: Cognitive Systems Engineering Framework

CACR

Centre for Applied Cognitive Research
Carleton University

Cognitive Systems Engineering Framework for Modeling and Simulation in the Acquisition Process

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Initial Report

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Cognitive Systems Engineering Framework

for Modeling and Simulation in the Acquisition Process

Summary

Military aircraft provide a forum for the development of new aviation technology that has potentially wide application. For example, heads-up displays, a technology that is common in military contexts, are just becoming widespread in commercial aircraft. In the past, the implications of human-machine interactions were rarely explored thoroughly when new technology was added to existing systems. With the development of affordable simulation environments, however, the feasibility of testing new technologies before they are installed in aircraft has increased substantially. Savings in terms of human costs and technology retrofits are potentially enormous. Furthermore, there have been recent advances in both our knowledge of human psychology and the capabilities of simulation environments, supporting a greater role for modeling and simulation (i.e., M&S). In this report, we propose a cognitive systems engineering (CSE) framework to guide the evaluation component of the M&S process. The goal of the CSE framework is to provide general guidelines for evaluating new technologies from the perspective of how these will affect the human-machine interface. This initial report consists of three parts. Section I is an overview of the proposed CSE framework. Section II is a more detailed literature review upon which the framework was based. Section III is a comprehensive bibliography.

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Section I: Proposed Cognitive Systems Engineering Framework

I.A. Overview of the Proposed Framework

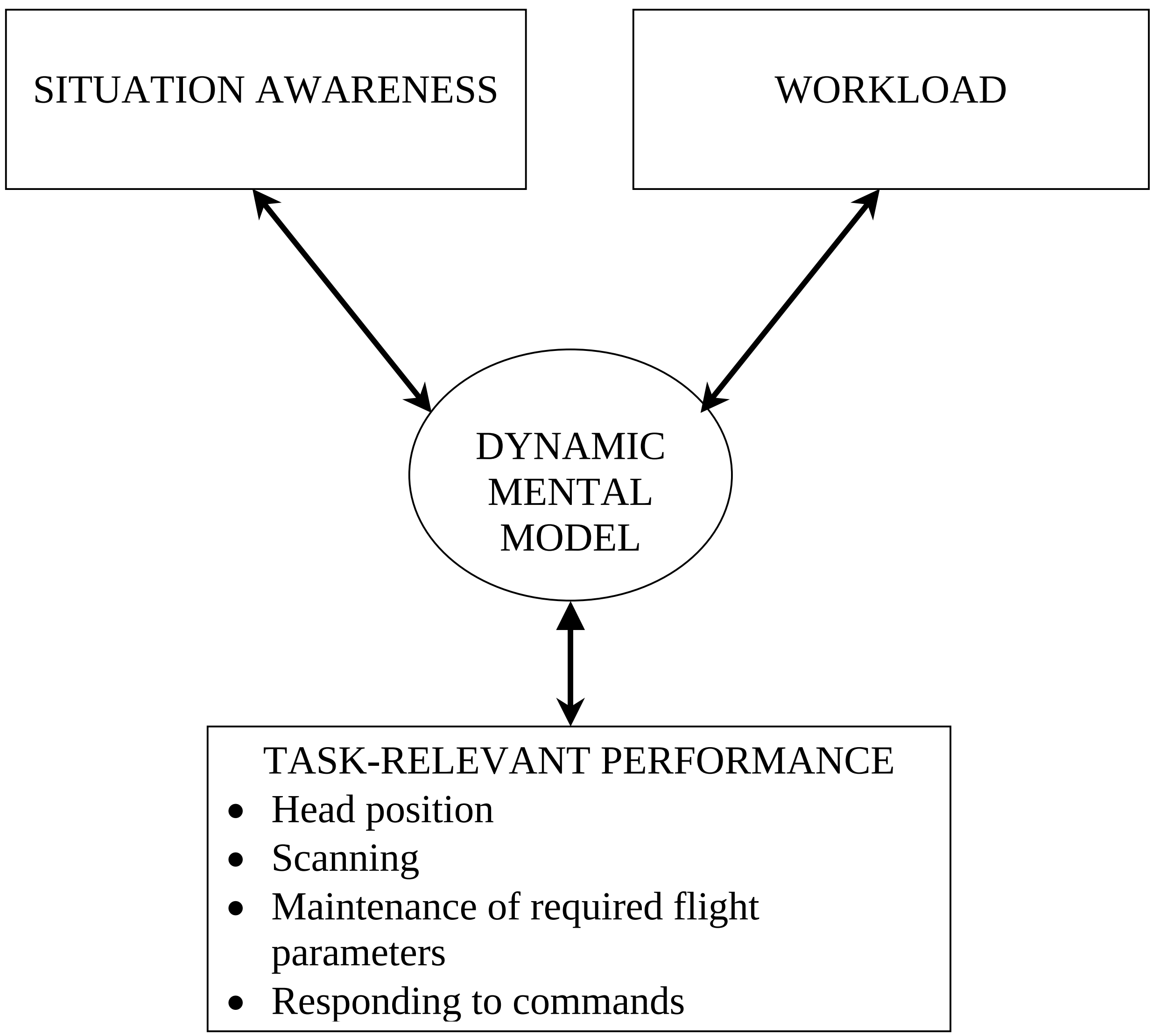
The proposed framework for evaluating new technologies in the M&S process is based on the application of a human factors approach to understanding cockpit design. In the Cognitive Systems Engineering (CSE) framework, we assume that the limitations of the human, rather than of the technology, must guide the development of new aviation systems. Pilots are extremely highly skilled operators of extremely complex machines. Improvements in technology must be designed around an understanding of the strengths and limitations of the human operator. Thus, the proposed CSE framework incorporates understanding of human cognition in a working blueprint for the design of evaluation experiments to support modeling and simulation in acquisition. As shown in Figure 1.1, the framework includes a theoretical construct, the dynamic mental model, and three empirical (i.e., measurable) constructs; situation awareness, workload, and task-relevant performance. Our review of the literature indicated that these three empirical constructs capture a large amount of the variance in the human-machine interface. The proximal goal of the CSE framework is to provide a context within which to interpret the dependent variables that are assessed in an M&S evaluation (i.e., how to assess the benefits of a new technology in a complex environment such as the Griffon CH146 helicopter). It is not intended to represent a complete model either of the human operator or of the situation, although further developments of the framework will be designed to expand the theoretical and predictive power of the model.

The central theoretical construct in the CSE framework is the dynamic mental model. It captures the notion that the human operator constantly creates and maintains an internal representation of the ongoing situation. When experimental methods are used to measure performance in an M&S evaluation, all of the measurements are inferences about the operator's dynamic mental model. The three empirical constructs, situation awareness, workload, and task-relevant performance, are assumed to provide a comprehensive (although not exhaustive) assessment of the dynamic mental model. Situation awareness, defined simply as "knowing what is going on around you" (Endsley, 2000, p. 5) is a construct that was proposed originally to capture why some fighter pilots were more successful (and therefore lived longer) than others (Spick, 1988). As discussed by Endsley (2000), SA is closely tied to knowing how to distinguish important information in the environment from less important information (selective attention), as well as the ability to quickly comprehend the importance of changes to elements in the environment.

The second empirical construct that forms the core of the CSE framework is workload. Workload is a familiar construct in aviation and has been studied more thoroughly than SA. Essentially, workload refers to the fact that humans are limited in their ability to process information and to respond appropriately. A helicopter pilot on a SAR mission who is flying with night vision goggles near the ground during a rain storm is likely to be in a situation of heavy workload. A large amount of information that changes rapidly has to be monitored and the pilot must constantly be updating his or her dynamic mental model of the environment. In contrast, a fighter pilot flying in good weather on a routine recce is probably in a low workload situation. Workload has proven to be a very useful construct for understanding changes in pilots' behaviour under different situational demands and constraints. Technology "improvements" should hypothetically decrease workload, but in practice, a technology that adds information to the pilot's environment and/or requires the pilot to perform additional tasks is more likely to increase workload. Thus, measuring changes in workload as a function of technology changes is crucial to understanding how that technology influences pilots' performance.

The third empirical construct in the framework, task-relevant performance, refers to the actions of the pilot (in relation to mission demands) that are potentially affected by the new technology. In essence, a new technology is expected to change some aspect of what the pilot knows and that knowledge will be reflected in his or her behaviour. Many other aspects of pilots' actions or behaviour might not change, however. The task-relevant performance that is relevant to any particular technological change will depend on what that technology was expected to influence. For example, the addition of a new display screen to the F-18 cockpit that has enhanced information about approaching threats should result in the pilot spending time looking at that screen and interacting with it in certain ways. Concomitantly, the F-18 pilot may spend less time using other sources of information, or may use that information differently. Thus, defining and measuring task-relevant performance is an important aspect of understanding the impact of a new technology on performance in the cockpit.

FIGURE 1.1 - CSE FRAMEWORK



In the CSE framework, the three experimental constructs (SA, workload, task-relevant performance) are second-order reflections of the pilot's dynamic mental model of the situation. Because it is impossible in practice to directly measure the contents of a human brain, use of multiple measures of the dynamic mental model is likely to provide more useful information than focusing on a single construct such as situation awareness. Furthermore, information acquired through the research process is limited by the types of measures chosen and by the underlying theoretical assumptions that guided the choice of those measures. In Section II, we present a detailed overview of the strengths and weaknesses of the constructs of situation awareness and workload. The bottom-line conclusion is that any single measure is unlikely to provide sufficient information to allow for general conclusions about the impact of a new technology on the crew.

Because it is impossible to directly measure the dynamic internal model (as it is not possible to directly measure "memory" or "thinking"), all measures we can use are behavioural in the sense that the pilot or crew must perform some action that is then assessed. For example, a subjective assessment of situation awareness requires that the pilot make a judgment or provide an evaluation. Head position could be used as an index of where the pilot is attending. Altitude maintenance could be used as an index of the pilot's adherence to the flight plan. In the case of SA, the simulation can be frozen and then pilots can be asked to report instrument information (such as altitude), or to make a prediction about the trajectory of enemy planes (i.e., bogies). Their answers to such queries are assumed to reflect their interrogation of their dynamic mental model (i.e., memory for the current location of bogies and knowledge about what those bogies are likely to do). In general, the researcher assumes that the behavioural responses or actions can be used as an index of the pilot's knowledge or mental processes.

Because of the complexity and multi-dimensional nature of the dynamic mental model, any single construct or any single measure of a construct is unlikely to capture sufficient information about the impact of a new technology. Instead, we propose that the CSE evaluation should include at least one, and preferably multiple measures of each of situation awareness, workload, and task-relevant performance. Use of multiple measures will allow for a richer and more accurate answer to the question "how does the new technology affect the human-machine interaction"? Below, we provide a detailed example of a previous M&S evaluation carried out by the CACR (in conjunction with CMC Electronics) that illustrates the importance of having multiple constructs and measures. Although this evaluation was conducted prior to the development of the CSE framework, it has characteristics that are consistent with the CSE approach that we are recommending.

I.B - Example: Direct Voice Input for the CH146 Griffon Helicopter

In designing and selecting measures (whether of performance, SA, or workload), it is important that these be constrained both by the specific situation (e.g., the CH146 environment) and the nature of the technological upgrade. Thus, the first step in an M&S evaluation is to do a rational analysis of how the technology is *expected* to influence pilot's behaviour. In the evaluation of direct voice input (DVI) for the Griffon, heads-up time was identified as a key variable that should be affected when pilots' were given DVI capabilities. Furthermore, heads-up time is an ecologically valid measure, because pilots are instructed and trained to spend as much time as possible looking outside of the aircraft. The DVI interface that was designed for the Griffon allowed the non-flying pilot to use voice commands for certain common actions that normally would be entered on the onboard computer (the CDU) that is located between the seats in the cockpit. For example, pilots could change the radio frequency by saying "SET RADIO 1 TO 121.5" instead of typing a series of commands on the CDU. Using a voice command meant that the non-flying pilot could potentially keep his or her eyes on the outside world. Because pilots are instructed to look outside the cockpit as much as possible, any increase in heads-up time would be a reasonable and logical outcome of the change from manual input to DVI. Heads-up time was measured in this evaluation by tracking the pilots' head position throughout the simulated recce missions, and then comparing the total heads-up time in the DVI condition to that in the manual input position. As predicted, heads-up time increased with DVI relative to the manual condition (by an impressive 42%), indicating that the technology change had at least one of the expected and desirable outcomes on pilots' behaviour.

Heads-up time is not the whole story, however. Although the CSE framework shown in Figure 1 had not been developed when the DVI study was planned, the researchers who conducted the evaluation recognized that multiple measures of behaviour would provide a more complete picture of the impact of DVI on the human-machine interaction. In particular, introduction of DVI to the Griffon cockpit had a variety of other potential effects. First, DVI had the potential to change the CRM in that the flying pilot now had the opportunity to interact with the CDU, whereas in the manual input situation only the non-flying pilot can enter commands on the CDU. So the workload or performance of the flying pilot might also be affected by the new technology. Second, if having to look at the CDU to enter commands was a workload-intensive activity for the nonflying pilot, then DVI might decrease his or her overall workload. Other aspects of the pilots' task performance, however, were unlikely to be affected in the types of missions that were flown.

Workload was measured in this experiment using detection of auditory and visual stimuli (i.e., targets) by both pilots. The targets (auditory tones or visual flashes in the external scene) were presented randomly in the course of the simulated missions. Pilots were instructed to respond as quickly as possible when they detected a target by pressing a key. Target detection as an index of workload has been used extensively and thus has both empirical and theoretical support. Essentially, the speed with which the pilot responds to the target can be used as a measure of his or her available mental capacity. In the DVI experiment, the workload of the non-flying pilot was less in the DVI condition that in the manual condition, suggesting that the DVI facility was likely to result in improved pilot performance. Importantly, however, the workload of the flying pilot increased significantly in the DVI condition. Even though the flying pilots infrequently used the DVI capability, the incremental change to their responsibilities was evident in the workload measure. In accord with the CSE framework, DVI had a significant impact on the flying pilot's dynamic mental model. This unexpected finding speaks to the complexity of changing the CRM as a function of the technological upgrades and to the importance of measuring multiple aspects of the overall pilot activities.

Situation awareness was not directly measured in the DVI experiment. Instead, it was inferred that SA would be better as heads-up time increased and workload decreased (Vidulich, 2000). Because inclusion of DVI capability resulted in a substantial increase in heads-up time and a decrease in workload for the nonflying pilot, it was concluded that the SA of nonflying pilots was likely to improve given DVI capabilities. In contrast, the SA of the flying pilot may be worse in DVI conditions, at least when they are allowed to use the DVI for commands that normally would be handled by the nonflying pilot. In summary, even though the DVI was conducted before our formalization of the CSE framework, it provides a concrete example of how multiple measures and converging evidence is necessary in the CSE process. Actual assessment of situation awareness would have provided an even more comprehensive picture of how DVI influenced cockpit activities.

I.C - Implications of the CSE Framework for Cockpit Research

Our review of the literature on cockpit research shows that workload, SA, and task-relevant performance capture a substantial amount of variability in the human-machine interaction. Workload refers to the cognitive effort required by the pilot, SA is the pilot's perception of events and integration of those events into a coherent understanding of the situation, and task-relevant performance captures the behaviours associated with the interactions between the human and the machine. Direct evaluation of performance provides important information about the pilot-system interface at the level of perceptual-motor coordination and thus allows for the evaluation of direct interaction with the system through systems control. Both SA and workload represent an aspect of the pilot-system interaction that does not directly reflect performance. Therefore, under some conditions, we should not expect a high correlation between SA or workload and the overall pilot-system interaction. Good SA does not always lead to good performance and high workload does not always predict poor performance. Nevertheless, these constructs are related and in many situations, good SA will predict good performance. More generally, the CSE framework emphasizes the importance of multiple interacting aspects of pilot behaviour.

Furthermore, the CSE framework makes an important distinction between the concepts that are being measured as part of the pilots' behaviour and concepts that are being measured as the underlying cognitive mechanism. One of the major problems in properly defining SA is a lack of distinction between SA as the measured construct and SA as the pilot's internal representation of the world (e.g., Endsley, 2000). SA originated as a description of behaviour (i.e., that some pilots are much more skilled than other pilots) but has often been used in the literature as the explanation for good performance (e.g., because the pilot has good SA, she performed well). This confusion between SA as an explanation and SA as a description needs to be avoided so that SA does not become circular and therefore an empty concept (Flach, 1995). .

A central tenet of the CSE framework, therefore, is that the human-machine interaction in the cockpit is too complex for a single concept to provide sufficient information to evaluate the impact of an interface on pilots' overall behaviour. By distinguishing among SA, workload, and performance and the underlying mental representation (the dynamic mental model), researchers can more clearly operationalize the concepts for empirical purposes. Research that is conducted within the CSE framework should allow for comprehensive and valid assessment of human factors aspects of new aviation technology.

Section II: Definitions and Literature Review

Reviews of situation awareness, workload, and related issues in cockpit research were done with various databases, including PsycINFO, Social Science Citation Index (SSCI), CISTISource and Web of Science. Pertinent references from other sources (e.g., conference proceedings of the Aviation Psychology conference) were also included. The edited bibliography of articles gathered via these searches is included at the end of this initial report. A reference list that includes those cited in the body of this report is also included. Our goal with the review portion of this report is to provide a critical overview of these psychological constructs, and to give recommendations that are pertinent to modeling and simulation activities relevant to the CH146. A third section (to be added in the final version of the report) will include descriptions of the results of Experiments 1 through 3, where the CSE framework was used to develop and implement the human factors component of the M&S process.

II.A. - Situation Awareness

II.A.1. - Defining Situation Awareness

Situation awareness, defined simply as "knowing what is going on around you" (Endsley, 2000, p. 5) is a construct that was proposed originally to capture why some fighter pilots were more successful (and therefore lived longer) than others (Spick, 1988). As discussed by Endsley (2000), SA is closely tied to knowing how to distinguish important information in the environment from less important information and to the ability to quickly comprehend the importance of changes to elements in the environment (Adams, Tenney, & Pew, 1995; Durso & Gronlund, 1999; Endsley, 1995; 2000; Sarter & Woods, 1995). Spick (1988) suggests that an important aspect of what made the aces better than the average pilot was their superior judgment about when to either engage in a fight or disengage in one that was not going well. Hence, SA represents pilots' ability to keep track of objects such as enemy aircraft in the environment and to estimate the probability of success in a given situation.

Situation awareness is appealing because it seems intuitively obvious that successful completion of missions requires that pilots are aware of the status of the aircraft and the various elements of the situation. It has proven difficult, however, to define what SA is for empirical purposes. Researchers offer different perspectives on what constitutes SA. This lack of a clear definition has made it difficult to establish a coherent framework for conducting SA research. Furthermore, researchers disagree as to whether or not SA is not a unitary phenomenon (Pew, 2000; Sarter & Woods, 1991). Researchers face a variety of difficulties in defining SA. First, SA encompasses a wide variety of factors such as keeping track of objects in the environment, attending to relevant information, and pilot's knowledge of the mission. Second, the elements of the situation that are relevant vary considerably depending on the nature of the mission and the aircraft. For example, although altitude tracking is critical to a helicopter pilot attempting to maintain a hover over the ocean, altitude tracking is not critical to a fighter pilot who is engaged with an enemy aircraft. These complexities have made it difficult to produce a single, definitive description of SA.

One commonality across different descriptions of SA is an emphasis on the underlying cognitive mechanisms that determine SA and that are common to different situations (Adams et al., 1995; Endsley, 2000). Endsley (1988) defined SA as: "…the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the future" (1988, p. 97). Endsley included three levels within the construct of SA: perception, comprehension and projection (Endsley, 1995, 2000). Endsley's model will be considered in some detail because it is the most widely cited description of the construct of SA.

Level 1 SA is the operator's perception of the current status of the environment. For instance, in a cockpit environment, Level 1 SA includes the perception of the various indicators on the display such as the altitude indicator, heading, and relative position. Level 1 also includes the perception of objects in the environment such as mountains, trees, other aircraft, and warning lights. Level 2 SA refers to how the situation is understood (i.e., how the various elements that are perceived at the earlier level are integrated and comprehended). At Level 2 SA the various elements perceived in the situation are integrated in light of the pilot's goal and the requirements of the task. At this level the pilot forms a holistic picture of the environment that combines the individual elements with stored knowledge of these elements. Level 3 SA refers to the pilot's ability to predict future status of the situational elements and to anticipate the requirements of the operating system. This is the highest level of SA and is based on the elements of both Levels 1 and 2.

Endsley (1995) proposed a theoretical model of SA. In her model Endsley describes SA as a dynamic mental model of the world that is determined by various cognitive factors such as attention, working memory, and prior knowledge. Unfortunately Endsley's model is far too complex to generate testable hypotheses or guide experiments. Also, it is not clear within the model whether measured SA is the behaviour of the pilot or the underlying cognitive state (Flach, 1995). Furthermore, Endsley emphasizes that SA as a cognitive state that is independent from performance. Therefore, performance measures often play a small role in cockpit evaluations unless specifically defined as being an indirect measure of SA. In summary, although Endsley's model has had considerable impact on the field of aviation psychology, it functions more as a way of describing the human-machine interaction, rather than as a framework for developing M&S research.

II.A.2 - Measuring Situation Awareness

In combination, Pew (2000) and Vidilich (2000) proposed five broad categories of measurement that have been used in research on situation awareness. As shown in Table 2.1, these include verbal protocols, awareness queries, subjective assessments, performance assessments, and situation manipulations. Pew (2000) provides the more comprehensive taxonomy of SA measures, however, Vidulich (2000) noted that researchers have often inferred SA from performance, rather than measuring it directly. In accord with the proposed CSE framework, measuring only SA or only workload is likely to be restrictive. The overlap between SA and performance noted by Vidulich supports our view that multiple constructs and multiple measures of these constructs are most likely to provide a comprehensive overview of the human-machine interaction.

Table 2.1

Taxonomy of Measurement for Situation Awareness (after Pew, 2000, and Vidulich, 2000)

Our terminology	Pew's Terminology [Vidulich][a]	Description
Verbal Protocols	Verbal protocols	Pilots provide online or immediately retrospective think-aloud descriptions of their mental processes
Situation Manipulations	Direct system performance measures	During the simulated mission, the experimenter: (a) introduces either an anomaly, or some kind of subtle scenario manipulation that the pilot is expected to detect if they have good SA (b) introduces disruptions that pilots must recover from (e.g., freeze the simulation, then introduce an offset to the heading) (c) introduces anomalous data or instrument readings and observes pilots' responses
Awareness Queries*	Direct experimental techniques [memory probe measures]	Pilots respond to queries or probes collected when a simulation is frozen (e.g., best known method is SAGAT; Endsley [2000])
Subjective Assessment*	Subjective measures	Self-assessments (usually after the mission has finished), expert judgments of pilot SA, peer ratings, supervisor or instructor ratings
Performance Assessment*		Experimenter makes an inference about effects of a technology on SA by evaluating changes in performance

[a] terminology used by Vidulich (2000) if it is different than that used by Pew (2000)

* categories included in Vidulich (2000) meta-analysis.

II.A.3 - Summary

SA represents how well the pilot perceives the situational elements and integrates them into a coherent understanding of the situation. Measurement of SA can show how a well-designed system supports the pilots' cognitive needs whereas a poorly designed system may result in pilots lacking a coherent understanding of their surroundings (Jones & Endsley, 1996). However, although SA provides important insight into some aspects of the pilot-system interaction, other aspects may be neglected. For example, by focusing on measuring a pilot's understanding of the situation, some critical aspects of behaviour may be overlooked. For example, perceptual-motor coordination that is reflected in how well the pilot maintains a route or reacts to stimuli in the environment is an important part of the overall adaptation to the requirements of the cockpit system. Thus, measurement of SA needs to be supplemented by other sources of information. The proposed CSE framework would help researchres to capture more of the variance involved in pilot-system interaction as compared to measuring a single construct. Thus, the goal of the CSE framework is to guide future research in this domain based on the assumption that multiple measures of three central constructs (i.e., SA, workload, and task-relevant performance), will give a reasonably complete perspective on how any given technology influences human responses in the cockpit.

II.B. - Workload

II.B.1 - Defining Workload

The concept of mental workload has been used in the aviation community to capture the relations among task difficulty, limitations in pilots' cognitive abilities, and performance (Flach & Kuperman, 2001; Wickens, 2001). Workload is an index of how much cognitive effort is required by pilots as they interact with a given system. Measuring workload is particularly relevant to cockpit research where the challenge is to reach a balance between the quantity of information provided and the pilots' capacity to process that information. In general, as more effort is required from the pilot for a given task, fewer cognitive resources are available for accomplishing other tasks. High workload is associated with emotional stress, fatigue, and decrements in performance (Hart & Wickens, 1990; Tsang & Wilson, 1997).

Workload has been defined as: “a hypothetical construct that represents the cost incurred by a human operator to achieve a particular level of performance” (Hart & Staveland, 1988, p.140). This definition of workload is framed within the resource model of information processing such that workload represents the relation between the availability of cognitive resources and the demands of the task (Wickens, 1991). Within this model, performance decrements occur when tasks that are being performed simultaneously require the same cognitive resources. This resource-based definition of workload is consistent with a large literature on the relations between mental effort and performance in a wide range of cognitive tasks. In aviation research, however, a disadvantage of this definition of workload is that it does not distinguish between how the pilot experiences the level of task difficulty and the actual impact it has on performance.

In the domain of aviation, researchers have placed more emphasis on the pilot's experience of workload (i.e., subjective workload) than on objective workload (i.e., performance trade-offs) by measuring physiological responses and asking pilots to rate their perceived workload (Hart & Wickens, 1990; Wickens, 1999). The focus on how pilots experience workload reflects the finding that, in highly trained pilots, high workload does not necessarily reflect poor performance (Vidulich & Wickens, 1986; Yeh & Wickens, 1988). Nevertheless, if the pilot experiences a task as demanding (i.e., high in workload), he or she may become fatigued and mission effectiveness may be compromised. A common pattern seen in workload research is that performance is stable for a long time and then suddenly declines. Initially, researchers assumed that the performance decrement reflected a sudden increase in workload that exceeded the pilots’ cognitive resources. However, subjective ratings and physiological measures showed that pilots actually experienced a steady increase in workload up to the point of the performance decrement (Andre, 2001).

In summary, both the objective workload (i.e., trade-offs between performance and effort) and subjective workload (i.e., the pilots’ perception of workload) are important aspects of the human-machine interface in research on aviation. However, although research suggests that workload measures are a valuable tool in aviation research, they have not been used consistently because there is no consensus in how workload should be measured (Flach & Kuperman, 2001; Wickens, 2001).

II.B.2 - Measuring workload

Numerous measures have been proposed to evaluate workload in the cockpit. The proposed measures of workload can be classified into four broadly defined categories; primary-task measures, secondary-task measures, physiological measures, and subjective ratings (Bortolussi, Kantowitz & Hart, 1986; Casali & Wierwille, 1984; Hart & Wickens, 1990; Wickens & Hollands, 1999).

Primary-task measures. Measuring performance on the primary task (i.e., the task required by the system in question) allows for the assessment of whether the task causes boredom and hence less vigilance over time, whether performance is stable over time, and at what point performance breaks down. However, performance on a primary task is rarely used to evaluate workload as it tends not to co-vary with pilots' experience of workload. Therefore, poor performance may or may not reflect demands on resources (Yeh & Wickens, 1988). Thus, primary task performance can be considered a baseline measure, but it is only directly indicative of workload when cognitive resources are exceeded and performance begins to break down.

Secondary- task measures. When pilots simultaneously perform two tasks, the primary task is the central aviation task (e.g., hovering) whereas the secondary task is added by the researcher to reflect the availability of cognitive resources. For example, in the DVI evaluation reported by Herdman et al. (2001), the primary task was to complete the mission whereas the secondary task was to detect the auditory and visual targets. The pilot is instructed to perform as well as possible on the primary task and allocate any leftover resources to the secondary task. As the primary task becomes more difficult, fewer resources are available for performing the secondary task and thus the focus is on decrements in performance on the secondary task. Common secondary tasks used to evaluate workload are: a) a rhythmic tapping task where the pilot must produce a finger or a foot tap at a constant rate, b) random number generation where the pilot must randomly generate numbers, and c) reaction time to probe stimuli (e.g., Herdman et al., 2001).

Secondary task measures have been used frequently to evaluate workload. However, the method has some limitations. First, when the primary task reaches a certain level of difficulty the pilots may simply abandon the secondary task. Second, research on workload using secondary measures has shown that different types of secondary measures will be interfered with selectively by the primary measure. For example, tapping is more likely to interfere with a spatial primary task than with a verbal primary task (Baddeley & Logie, 1999). This selective interference means that the workload differences caused by the primary task may be underestimated if the primary and secondary tasks require different processing resources (see Hart & Wickens, 1990). Third, introducing a secondary task to the pilot may be intrusive for the pilot. Despite these limitations, however, secondary task measures provide a very useful objective index of pilot workload. Furthermore, the use of the dual-task method is a well-established way of indexing cognitive demands in the wider literature (Baddeley & Logie, 1999) and thus considerable research can be accessed to develop and interpret the results of workload research in the aviation field.

Physiological measures. Physiological measures of workload include heart rate, eye blink rate, pupil diameter, respiration frequency, blood pressure, and electrical activity of the brain. Use of these measures is based on the assumption that, for example, an increase in heart rate or respiration reflects a concomitant (but not necessarily conscious) increase in workload. One advantage of physiological measures is that they are less obtrusive than subjective ratings or secondary task measures. Furthermore, measurement of physiological responses provides information about the pilots' emotional and physical activation during the course of a task as well as their processing time and cognitive load. Researchers have shown that physiological measures are a reliable indication of workload (Bortolussi, Kantowitz & Hart, 1986; Casali & Wierwille, 1984). However, the main limitation of physiological measures is that they are indirect indices of how the pilot actually experiences the workload. Furthermore, physiological measures may not relate directly to performance. [1]

Subjective evaluation. Subjective ratings of workload have been used most frequently in research on aviation. They have the advantage of directly measuring the pilots' experience of workload in terms of cognitive cost and attentional resources (Hart & Wickens, 1990). Two questionnaire measures are commonly used in evaluating the pilots' experience of workload, the NASA task load index (NASA TLX; Hart & Staveland, 1988) and the subjective workload assessment technique (SWAT; Reid & Nygren, 1988). The NASA TLX assesses workload on

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[1] Although visual scanning or other measures of behavior are sometimes classified as "physiological measures", in the CSE framework these would be considered as elements of "task-relevant performance". Visual scanning is a very indirect measure of physiological processes.

five 7-point scales; mental demand, physical demand, temporal demand, performance, effort, and frustration level. The SWAT assesses workload on three 3-point scales; time load, mental effort, and stress.

Subjective ratings of workload are widely used. Subjective ratings are relatively easy to administer and have minimal impact on pilots' ongoing behaviour because they are typically given after a task is completed. These measures are limited, however, because they are rarely used to index online workload (i.e., workload that is experienced while the pilot is doing the task) and because they are subjective. As with any measure that requires pilots to introspect on their behaviour, there are always questions about whether such measures are reliable (i.e., are the measures consistent? Can pilots' calibrate their responses across tasks?) and valid (i.e., do the responses actually reflect workload?; Wickens, 1999). Furthermore, rating scales are limited in that they will only tap into a subset of factors that may be relevant to the overall experience of workload (Hart & Wickens, 1990). More research in which subjective measures are collected in conjunction with objective measures is needed to probe the validity of these assessments.

II.B.3 - Summary

In aviation research, assessment of workload is important for evaluating the adequacy and feasibility of the human-machine interaction. High workload may reflect a poorly designed system that puts an unnecessary load on the pilot. For example, an instrument layout in the cockpit that requires longer gaze time by pilots than an alternative layout may increase pilot workload. Similarly, Herdman et al. (2001) found that the addition of a DVI system to the CH146 cockpit resulted in an increase in the workload of the flying pilot (as indexed by the secondary task performance). Hence, it is crucial to measure pilot workload in any technology evaluation. Although four categories of workload measurement have been described (i.e., primary-task measures, secondary-task measures, physiological measures and subjective ratings), multiple measures have rarely been used in the same studies. Furthermore, workload measures have not been used consistently in cockpit research (Wickens, 2001). As with performance and situation awareness, converging measures of workload are most likely to provide a comprehensive understanding of the impact of technology on the cockpit activity.

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Annex E – Report 2: Experiment 1

CACR

Centre for Applied Cognitive Research

Carleton University

Situation Awareness, Performance, and Workload in Simulated Flight: Head-Up Display (HUD) versus Head-Down Display (HDD)

TAMSS SA PROJECT

Report on Experiment 1

12 December 2002

Situation Awareness, Performance, and Workload in Simulated Flight:

Head-Up Display (HUD) versus Head-Down Display (HDD)

TAMSS SA

Report on Experiment 1

12 December 2002

Contract Serial No. 007SV-W7714-010547

Prepared by

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Executive Summary

Recent advances in both knowledge of human psychology and the capabilities of simulation environments support a greater role for modeling and simulation (i.e., M&S) in human factors research, system/equipment acquisition, and in the development of training programs. As part of the Tactical Aviation Mission System Simulation (TAMSS) initiative, the Centre for Applied Cognitive Research (CACR) at Carleton University has proposed a Cognitive Systems Engineering (CSE) framework to be used as a guide for conducting and interpreting evaluations in M&S programs. The present document includes a report on an initial experiment conducted at the CACR using the CSE framework. In accord with the CSE framework, the results of the experiment demonstrate the importance of collecting converging measures of pilot performance, workload, and situation awareness. The present document also includes an overview of the development and current capability of the CACR simulator research facility.

REVISION PAGE

REVISION LETTER	PAGES AFFECTED	DATE	APPROVAL

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Situation Awareness, Performance, and Workload in Simulated Flight: Head-Up Display (HUD) versus Head-Down Display (HDD)

This document has two main sections. In Section I, a report is given on the initial experiment in the TAMSS SA program. In this experiment, the Cognitive Systems Engineering (CSE) framework that has been proposed by the Carleton University Centre for Applied Cognitive Research (CACR) was used to evaluate the human-machine interface in two conditions, head-up versus head-down displays. In accord with the CSE framework, the experiment demonstrates the utility of collecting converging measures of pilot performance, workload, and situation awareness (SA) in modelling and simulation (M&S) efforts. In Section II, an overview is given of the development and current capability of the CACR simulator research facility.

Section I: Experiment

1.1 Introduction

1.1.1 Goals

The goals of this experiment were to (a) provide a preliminary evaluation of the Cognitive System Engineering (CSE) framework (see Annex A) proposed by the CACR for evaluating the impact of novel technology on aircrew in the CH146 Griffon helicopter and (b) develop and test the experimental capabilities of the Carleton University simulator facility.

In this experiment, pilots flew a series of simplified recce-type missions while wearing a HMD. Two primary conditions were compared: HUD versus HDD. In the HUD condition, the HMD was equipped with HUD symbology showing primary flight, power, and navigation information. The HUD symbology was derived from the CH146 Griffon LATEF II HUD. In the

HDD condition, the HMD was not equipped with HUD symbology. Instead, pilots were required to look under the HMD to acquire the requisite information from the head-down instrument panel. The HDD condition is similar to that faced by CH146 Griffon pilots using Night Vision Goggles (NVGs): when the NVGs are not equipped with a HUD, the pilots must look under the goggles to read information from the instrument panel.

The experiment was designed to sample all three dimensions of behaviour outlined in the CSE framework: task-relevant performance, workload, and situation awareness. Furthermore, the main thrust of the CSE framework is to provide converging measures, allowing researchers to give an overall perspective of performance that does not rely solely on a single construct or single method of measurement. Both subjective and objective measures of each dimension were developed. Although the TAMSS SA project is focused on situation awareness, we contend that assessing SA in isolation will not provide sufficient evidence to allow for good decisions in the modelling and simulation process.

1.1.2 Overview of measures

Task-relevant Performance - In this experiment, pilots flew simplified recce-type missions. On each mission, they initially took off from a base, located centrally in the terrain. They were then directed to find a series of waypoints (towers placed in the terrain) by an experimenter who gave them heading values. During the course of the recce, pilots were instructed to provide reports of (sitreps) any and all activity (in the air or on the ground). Each scenario was populated with a variety of objects such as fighter jets, rotary-wing aircraft, and land vehicles. These objects varied in visibility, but all were visible for a minimum of 2 to 3 seconds in daylight conditions. Although performance was measured exhaustively, our focus in this report is on deviations from assigned speed and altitude values. Subjective ratings of performance and of task difficulty were collected after each mission.

Workload - Workload was assessed through the presentation of auditory and visual probes. Both the latency to the probes and the percentage of probes missed was measured. Subjective ratings of workload, globally and during specific legs of the recce, were also collected.

Situation Awareness - The objective index of situation awareness was the percentage of objects that pilots missed during each mission. After each mission, pilots also rated their perceived awareness overall and for specific flight parameters (speed, altitude, and heading), and for activity in the environment.

1.1.3 Predictions

The pilots who volunteered for this study were all highly experienced with rotary-wing aircraft. However, none of the pilots had experience with the HUD symbology. Thus, differences due to familiarity of the standard instruments versus the HUD symbology would be expected, especially where the information conveyed by the symbology was in a very different form from that of the instruments (e.g., speed on a dial versus speed in numbers). Furthermore, although HUDs have been shown to be effective in specific tasks such as controlling flight path and altitude (e.g., see Fadden, Ververs, & Wickens, 2001; Martin-Emerson & Wickens, 1997; Wickens & Long, 1995), there are a number of simulator-based studies suggesting that pilots may focus or ‘cognitively tunnel’ their attention on HUD symbology (Brickner, 1989; Fischer, Haines, & Price, 1980; Foyle, Stanford, & McCann, 1991, Wickens & Long, 1995). Cognitive tunneling may cause pilots to miss potentially critical events in the external scene. For example, Fisher et al. found that in a simulated landing task, pilots were less likely to detect a runway incursion (e.g., a vehicle driven onto a runway) when they were using a HUD than when they were using a conventional head-down display. In the present research the object detection task was more naturalistic than those used in previous simulator-based studies of cognitive tunneling. Because attentional capture is a potential side effect of HUDs, it was predicted that pilots who are not familiar with HUDs would show evidence for cognitive tunnelling.

1.2 Method

1.2.1 Participants

Four male pilots participated in this experiment. They ranged in age from 37 to 50 years. The pilots had between 10 and 29 years experience, with 1800 – 4800 hours total flight time and 780 – 1200 total hours in the Griffon. None had any experience using either fixed panel or HMD HUDs. Thus, all were seasoned pilots but novice HUD users.

1.2.2 Design

The central independent variable in this experiment was a comparison of the HUD versus the HDD. The objective and subjective measures of the three core constructs, situation awareness, workload, and task-relevant performance are shown in Table 1.1.

Table 1.1: Description of Dependent Measures

	Type of Measure	
CSE Domain	**Objective**	**Subjective**
Task-Relevant Performance	Deviation from assigned speed, altitude, and heading	Ratings of performance and task difficulty
Situation Awareness	Percentage of objects detected in the external scene	Ratings of SA (specific and global)
Workload	Auditory and Visual probe detection (percentage detected and mean detection latencies)	Ratings of workload

1.2.3 Materials

Questionnaires - The subjective measurements of situation awareness, workload, and performance were conducted at the end of each mission and at the end of the experiment. Pilots rated these variables on a number of scales (refer to Annex B). In addition, before starting the experiment, pilots completed a background questionnaire (see Annex B), which included questions about the number of tactical, Griffon, and HUD (heads-up display) flying hours they had logged.

Development of Mission Scenarios - The scenarios for the experiment were developed using the input from a subject-matter expert (SME) provided by DND to set up realistic missions for the pilots to complete. Numerous entities were added to the terrain database, creating scenarios that would allow the experimenters to take measures of Situation Awareness, Workload, and Task-relevant performance. The following is a description of the database used and the additions made to the external scene for the purposes of the experiment.

Terrain database - The landscape database was a Virtual Reality model of a 10 km by 10 km section of CFB Gagetown, NB. The database contained a number of fixed, pre-determined geographical features (river, hills, forest) and man-made elements (barracks, various military installations, roads, and the flight base). Various entities, both moving and stationary, were added to the terrain database to create a number of mission scenarios (see below). Some of the entities were fixed navigation landmarks, which allowed pilots to follow pre-determined flight paths as instructed by the experimenters. Other entities added to the terrain, such as military vehicles and armaments, were used to assess pilots' situation awareness during missions.

Navigation landmarks - Eight fixed objects were used as markers to indicate the waypoints that made up specific flight routes. They were placed at the four corners of the database terrain and midway between the corners on each edge, roughly 0.5 km in from the edges. The markers themselves were 10 m tall white rectangular parallelepipeds with a square base (i.e., tall white narrow boxes) that were visible up to 5 km away. These markers were chosen because of their high visibility in the HMD goggles. They were inserted into the terrain database using the STAGE program.

Objects used for assessing pilot SA - A number of objects were included in the simulation in order to provide pilots with entities to report during their missions. Objects were inserted and controlled using the STAGE software, with the exception of one wrecked helicopter, which was inserted using the VEGA environment. The objects included (a) two moving formations of three armoured ground cars, (b) three stationary pieces of artillery (Howitzer guns), (c) four grounded CH-149 Cormorant helicopters, (d) one wrecked CH-149, (e) two CH-149s flying in small loop formations, (f) two hovering CH-146 Griffon helicopters, (g) one formation of four CF-18s flying in a wide formation across a large portion of the terrain, and (h) one C-130 Hercules fixed-wing transport aircraft flying a slow, elongated loop pattern that cut across the whole width of the database terrain, roughly five kilometres from the southern edge of the terrain. All vehicles were placed so that they were on, or intersected, the paths that pilots flew in their missions. Hence, most vehicles were close to the edges or on the diagonals of the square formed by the database, and were either on the ground or at a fairly low altitude (below 300 feet). The CF-18s and the C-130 flew relatively slow and wide trajectories that intersected the pre-planned mission routes at fairly regular intervals. All entities were scaled to their normal size relative to the database.

Mission Scenarios - Two separate terrain databases were used in the experiments. Each database contained the same geographical features, buildings, waypoint markers, and entities, and differed only in that the entities had different locations and trajectories in each database. Each pilot flew four missions in each terrain (one terrain on the first day of their participation, the other on the second day), for a total of eight missions per pilot. Missions were limited to four per terrain to minimize the likelihood that pilots would rely on memory to report visual contacts with SA assessment objects.

Each mission consisted of flight legs (defined as a trajectory between two successive waypoint markers) arranged in a different order. The flight legs were sequenced such that (1) each waypoint was reached once per mission, (2) all the SA assessment objects were included on the path and distributed approximately equally between the legs of the mission, and (3) the legs constituted a continuous path starting and ending at the base. Consequently, two successive legs could either be collinear or at an angle to each other (either 45º or 90º depending on whether both legs were on the edges of the database, or one was on a diagonal between a corner waypoint marker and the base). Thus each mission was defined as a specific path visiting all eight waypoints, and was determined prior to starting the experiments. Examples of the mission routes and positions of the vehicles are provided in Annex C.

1.2.4 Procedure

Upon arrival, the pilots were provided with some information about the experiment and were given an overview of the two-day schedule. Pilots then completed an informed consent and the background questionnaire. Following the information session, the pilots flew three practice sessions before beginning the first of eight experimental sessions. The practice sessions consisted of a simulated flight using the full OTW scene, a second flight using the HMD without the HUD, and a final practice mission using the HMD with the HUD. Prior to beginning the practice flights, the pilots were briefed on the functionalities of the HUD symbology. During all three practice sessions the pilots were required to report on any activity (e.g., aircraft, ground vehicles) seen during the mission. After a brief break, the pilots flew the first experimental mission. Their task during each experimental mission was to follow the designated flight path while maintaining the assigned speed and altitude. There were also to report any activity occurring on the ground or in the air throughout the mission.

During Mission 1, Pilots 1 and 2 flew using the HMD without the HUD. For Mission 2, they flew using the HMD with the HUD. For the remaining six missions, Pilots 1 and 2 alternated between flying with the HUD and flying without the HUD. In contrast, Pilots 3 and 4 flew their first mission using the HMD with the HUD and flew the second mission using the HMD without HUD. Pilots 3 and 4 also alternated between the HUD and no-HUD conditions for the remaining missions.

During the final HUD mission, the experimenters froze the heading tape for approximately 15 -30 seconds to test "freezing the instruments" as a possible measure of SA in future experiments.

Workload. In half the missions (two with the HUD and two without the HUD) the pilots were instructed to respond as quickly as possible to auditory and visual probes. The visual probe consisted of a light that appeared for 500 ms at the center of the pilot's field-of-vision (FOV) at random time intervals (i.e., every 15 seconds plus or minus 20% during the mission).[1] The auditory probe was a randomly presented tone, also presented briefly (500 ms) every 15 seconds (i.e., plus or minus 20%). Upon detecting an auditory or visual probe, pilots were to respond by pushing a button on the cyclic as quickly as possible. Only one type of probe (visual or auditory) was presented during a particular mission and the pilot was informed about the type probe before each mission.

In total, each pilot completed eight missions, four with the HUD and four with the HDD. Four experimental missions were flown on day one with the other four completed on day two. Each scenario began at the base (in the center of the terrain). Pilots were instructed to take off from the base, and then head in a direction indicated by the experimenter. The pilot was directed to a waypoint marker with compass directions. Once the pilot had visually identified the waypoint, they were given a new heading and were instructed to take an inside turn (if possible) around the tower and go to the new heading. A sample flight scenario through the terrain is shown in Annex C.

Pilots were instructed to climb to a height of 200 m and maintain airspeed of 80 knots over the course of the mission. The main goal of the mission, however, was for the pilots to verbally report the presence of objects in the environment. In each experimental condition, the defined heading directions were communicated to the pilots by one of the experimenter using the simulator intercom system. A second experimenter recorded the appearance of the objects, whether or not the pilot reported seeing the objects, and the approximate distance between the helicopter and the object when the pilot reported it. Whenever the pilot spotted an object, they were to report it immediately and to provide detail that they determined was relevant (e.g., type of object, direction object was heading etc.). The number of missed objects was also recorded. The two experimenters viewed two computer screens located behind the pilot. One showed the actual scene the pilots saw at any given point in time, and the other showed the location of the ownship on a map of the database. Thus, both experimenters had full access to the scene being viewed by the pilot and could monitor pilot activities and the movement of the aircraft. The experimenters reminded the pilots of these headings when they deviated from them. Upon reaching each waypoint a new heading (north, south, west, east) was given for the next waypoint.

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[1] Due to a failure to log experimental data, complete visual probe data is not available for two pilots.

When the pilots had successfully completed the mission, they were instructed to return to the base. Upon reaching the base, the simulation was frozen and the experimental session ended.

Each mission took approximately 20 minutes to complete. After each mission, the pilots were asked to fill out a questionnaire that concerned their awareness of objects, events, and instrument readings during the flight (see Annex B). While one pilot was filling out his questionnaire, the second pilot flew his next mission. At the end of the second day the pilots were asked to fill out a final questionnaire asking about their experiences with the HUD versus the HDD condition.

1.3 Results

1.3.1. Missions

The main focus of data analyses was a comparison of the HUD vs. HDD conditions. Objective measures of task-relevant performance including average deviations for speed and altitude were taken during each mission. The objective measure of SA was the percentage of objects missed during each mission. The objective measures of workload were the percentage of auditory and visual probes detected, and the average speed with which pilots responded to these probes. The average levels of performance for each of the objective measures are shown in Table 1.2. Differences between the HUD and HDD conditions were tested with directional t-tests (i.e., based on previous research, the HUD condition was predicted to result in worse performance than the HDD condition).

Table 1.2: Objective Measures of Performance, Workload, and Situation Awareness

	Flight Condition				
	HUD		HDD		
	M	*SD*	*M*	*SD*	*t(3)*
Situation Awareness					
% Objects Missed (all)	**48.5**	**14.0**	**37.5**	**11.9**	**2.82***
• In air	**46.9**	**15.6**	**31.5**	**14.3**	**14.38****
• On ground	51.4	16.2	45.9	9.9	0.63
Workload					
Auditory % Errors	**17.6**	**16.0**	**9.9**	**8.4**	**1.85†**
Visual % Errors[a]	37.2	41.7	27.3	17.9	-
Visual RT (ms)[a]	980	313	921	183	-
Auditory RT (ms)	647	147	585	54	0.95
Performance (RMSD)					
Speed	6.7	1.9	6.6	0.3	0.18
Altitude	23.4	6.9	24.9	4.9	-0.61

[a] Based on two pilots only. † $p < .10$, * $p < .05$, ** $p < .01$

The most dramatic result in Table 1.2 was that the pilots' objective situation awareness was worse in the HUD than in the HDD condition. Pilots missed more objects in the HUD condition than in the HDD condition, with the airborne objects (i.e., F18s, Hercules, and other helicopters) showing the greater effect. These SA differences between the HUD vs. HDD conditions do not appear to be due to relative duration or relative visibility of the various objects, as there was a considerable range for both airborne and ground-based objects.

Workload also was higher in the HUD than in the HDD condition, such that pilots missed more of the auditory and visual probes (i.e., tones and light flashes) when they were using HUD symbology than when they were using the instruments. Similarly, their response times to the probes were also slower in the HUD than in the HDD condition. Although none of the workload differences were statistically significant, the consistent pattern of differences and the substantially larger amount of variability shown in the HUD condition suggest that the measures were sensitive to workload differences but that there was considerable cross-pilot variability.

In contrast to the workload and SA measures, task-relevant performance (i.e., average RMSD deviations from speed and altitude) did not vary across conditions (see Table 1.2). Pilots were able to maintain flight parameters within reasonable boundaries in both HUD and HDD conditions. This pattern (differences for SA and workload but not for performance) contrasts with that found for the subjective measures, as described below. It appears that difficulties with the HUD symbology resulted in different subjective and objective assessments.

After each mission, pilots completed a subjective questionnaire in which they rated their performance, workload, and situation awareness. The mean ratings on each question are shown in Tables 1.3, 1.4, and 1.5. As shown in Table 1.3, objective and subjective measures showed moderate convergence in this experiment. Pilots rated their overall SA as somewhat worse in the HUD than in the HDD condition, in accord with their actual performance on the object detection task. They also rated their awareness of airspeed and of activity on the ground as worse with the HUD. However, they did not perceive their performance on detecting activity in the air as worse with the HUD, suggesting that their subjective access to specific aspects of their SA was low. These results do suggest that the questionnaire is sensitive to variations in perceived SA.

Table 1.3: Subjective Measures of Situation Awareness

	Flight Condition				
	HUD		HDD		
	M	*SD*	*M*	*SD*	t(3)
Overall Situation Awareness	**5.0**	**0.4**	**5.4**	**0.5**	**-2.05†**
Aviation:					
Heading	4.8	0.3	4.9	0.1	-0.25
Airspeed	**3.4**	**0.4**	**4.0**	**0.3**	**-3.06***
Altitude	4.3	0.8	4.6	0.4	-0.85
Attitude	4.8	0.6	4.8	0.5	0.40
Aircraft Systems	4.2	1.0	4.3	0.6	-0.44
OTW Events:					
Activity on the ground	**4.4**	**1.0**	**4.7**	**0.8**	**-2.43***
Activity in the air	4.9	0.6	4.9	0.6	-0.20
Environmental Events	5.2	0.5	5.0	0.8	0.70
Spatial Orientation	5.5	0.3	5.4	0.5	0.13

Note: Situation Awareness; 1 = low; 4 = moderate; 7 = high
† $p < .10$, * $p < .05$, ** $p < .01$

Ratings of workload are shown in Table 1.4. Subjectively, pilots did not rate their workload as different in the HUD versus the HDD condition. This contrasts to the trend for the objective measures of workload, which suggest that workload was greater with the HUD. Instead, pilots rated their *performance* as worse with the HUD than with the instruments, as shown in Table 1.5. They indicated that their performance on maintaining speed, altitude, cross-checking their instruments, and using information from the external scene was worse with the HUD than with the HDD. This latter rating, in particular, suggests that pilots were aware that they were less able to fulfill all the demands of the missions with the HUD, but that a direct question about performance was more sensitive to these differences than questions about SA or workload. One possible explanation of these results is that pilots are more able to evaluate their performance (because they have direct experience of it) than to evaluate workload or SA, which are hypothetical constructs that may have different subjective meanings to different individuals.

Table 1.4: Subjective Measures of Workload

	Flight Condition				
	HUD		HDD		
	M	*SD*	*M*	*SD*	t(3)
At waypoints	3.2	0.4	3.2	0.7	0.12
Between Waypoints	3.6	0.6	3.9	0.8	-1.31
When Reporting Targets	4.0	0.8	3.9	0.8	0.63
Overall	3.5	0.6	3.6	0.8	-0.73

Note: Workload; 1 = low; 4 = moderate; 7 = high
† $p < .10$, * $p < .05$, ** $p < .01$

Table 1.5: Subjective Measures of Performance

	Flight Condition				
	HUD		HDD		
	M	*SD*	*M*	*SD*	t(3)
Finding Waypoints	5.4	0.8	5.7	0.5	-0.91
Maintaining Heading	5.1	0.6	5.1	0.5	.00
Maintaining Speed	**3.4**	**0.6**	**4.2**	**0.4**	**-5.38****
Maintaining Altitude	**3.2**	**0.5**	**4.7**	**0.2**	**-4.61****
Cross Checking Instruments	**4.2**	**0.6**	**5.2**	**0.1**	**-3.93****
Using Information from the External Scene	**4.7**	**0.6**	**5.2**	**0.4**	**-2.47***

Note: Performance Ratings; 1 = very poor; 4 = adequate; 7 = very good
† $p < .10$, * $p < .05$, ** $p < .01$

This interpretation of the differential sensitivity of the less direct subjective assessments (i.e., SA and workload) versus more direct subjective assessments (i.e., performance) is supported by the results of the subjective ratings of task difficulty and difficulty of using the available information, as shown in Table 1.6. Pilots indicated that they found it more difficult to maintain speed and altitude with the HUD than with the HDD. They also found it more difficult to use information about speed from the HUD than from the HDD. These differences in task difficulty and useability may be due to the substantial changes in the representation of speed and altitude between the two presentation modes. On the familiar instrument panel, speed is represented as a dial (analogue) whereas on the HUD, speed is represented digitally (numerical display). Similarly, altitude is represented as a dial on the HDD panel, but as a combined bar and numerical index on the HUD. Seemingly trivial differences in how stimuli are represented can have a significant influence on how those stimuli are processed, particularly when one representation is very familiar and the other is unfamiliar or unusual because different mental codes can be activated by different inputs. Consistently, the pilots rated their performance, SA, and the perceived difficulty of processing speed and altitude as greater in the HUD than in the HDD condition. These findings indicate that the questionnaire was sensitive to these variations in the technology.

Table 1.6: Subjective Ratings of Task Difficulty and Difficulty of Using Available Information

	Flight Condition				
	HUD		HDD		
	M	*SD*	*M*	*SD*	t(3)
Task Difficulty Ratings					
Finding Waypoints	2.2	0.6	2.4	0.8	-1.04
Maintaining Heading	2.9	0.5	3.2	0.5	-1.84
Maintaining Altitude	**4.8**	**0.5**	**3.9**	**0.4**	**8.23****
Maintaining Speed	**4.6**	**0.7**	**3.7**	**0.9**	**5.02****
Cross Checking Ins	3.7	0.7	3.3	0.9	0.71
Use External Scene	2.8	0.7	2.9	1.0	-0.04
Useability Ratings					
Heading	2.7	0.5	3.2	0.9	-1.33
Altitude	3.6	1.4	3.0	0.7	1.31
Speed	**4.9**	**0.4**	**3.4**	**0.5**	**3.51****
Attitude	**3.7**	**1.3**	**3.2**	**0.7**	**1.65†**
External Scene	2.9	1.0	2.8	0.7	0.37

Note: Difficulty ratings: 1=very easy, 4 = moderate, 7 = very hard
† $p < .10$, * $p < .05$, ** $p < .01$

In contrast to the difficulties that pilots reported with speed and altitude information, they tended to rate maintaining heading as somewhat easier with the HUD than with the HDD, despite the unfamiliar representation of heading (i.e., heading tape) in the HUD versus the familiar format (i.e., compass) in the HDD. The trend suggests that the questionnaire is sensitive to positive as well as negative differences in representations of instruments.

Finally, as noted in the Procedure section, the heading information was frozen for approximately 15 – 30 seconds for pilots sometime during their last HUD mission. None of the pilots reported noticing that the heading tape had been frozen. Freezing the instruments may be an interesting (albeit limited) way to index SA in future research. It is limited because overuse of this approach might sensitize the pilots to potential problems with the instruments and cause even more cognitive tunneling on the HUD, an outcome that could interfere with the interpretation of the results.

1.3.2 - Post Experiment Comparison of HUD to HDD

At the end of the second day of testing, pilots compared the HUD and HDD conditions on a variety of measures, similar to those they had been evaluating throughout the experiment (See Annex B). To test whether the pilots perceived a difference between the two conditions, mean ratings were compared to the value ‘4’ representing “no difference” between the HUD and HDD conditions. The mean values and standard errors are shown in Table 1.7.

Table 1.7: Comparison between HUD and HDD Flight

	M	*SE*	*t(3)*
Overall situation awareness	4.3	0.8	0.29
Awareness of heading	3.5	1.3	-0.40
Awareness of altitude	4.0	1.2	0.00
Awareness of airspeed	3.5	0.6	-0.77
Awareness of spatial orientation	3.5	0.5	-1.00
Awareness of activity on the ground	4.3	0.5	0.52
Awareness of activity in the air	4.5	0.6	0.77
Awareness of aircraft systems	4.3	1.5	0.38
Cross checking relevant instruments /symbology	4.3	0.8	0.29
Using information from the scene to control the aircraft	3.8	0.3	-1.00
Eyes-out time	1.8	0.3	-9.00**
Low-level flight	2.8	0.6	-1.99
Low-level maneuvering	3.0	0.8	-1.22
Maintaining airspeed	4.0	0.7	0.00
Maintaining heading	3.5	0.6	-0.77
Maintaining altitude	4.5	0.9	0.58

Note: 1 = HUD much better; 4 = no difference; 7 = instruments much better
** $p < .01$

All four pilots rated the HUD as much better than the HDD condition for increasing "eyes out" time. Thus, pilots perceived an advantage for the HUD only in the sense that they felt they were more likely to be looking out of the cockpit. As is evident from both SA performance and from ratings, however, the HUD was not better for gaining flight information and was worse for actually noticing objects in the environment. Although pilots reported some difficulties and perceived performance decrements with the HUD, they did not translate this into an overall more negative evaluation. It is clear that the combination of the subjective and objective measures is important for understanding the effects of the unfamiliar HUD symbology on workload, situation awareness, and performance.

1.4 Discussion

The results of this experiment support the validity of the CSE framework for evaluating

M&S assessment of technology. Pilots reported performance differences with unfamiliar (HUD condition) versus familiar (HDD condition) versions of the instruments. These perceived performance decrements were reflected in poorer SA, specifically resulting in a decrease in pilots' ability to report the presence of objects such as fighter jets and other helicopters in the external scene. Pilots' objective workload was also worse when using the unfamiliar HUD symbology, suggesting that they experienced either a high level of workload or cognitive tunneling. Furthermore, pilots showed a tendency to rate their overall SA as slightly better in the HDD condition than with the HUD condition, but did not perceive differences in workload. Thus, the combination of measures used in this study showed that although patterns of situation awareness, workload, and task-relevant performance varied across the HUD and HDD conditions, the objective and subjective indices of these constructs were not always perfectly aligned.

The overall level of SA shown by these pilots was moderate – even in the HDD condition, they missed approximately 40% of the objects in the OTW scene. In actual flight, of course, the pilot's eyes are augmented by those of the other crewmembers and their performance occurs as part of a team effort. Furthermore, these particular pilots had no direct experience with HUDs and the two aspects of the task that they found most difficult, maintaining speed and altitude, are arguably the indices that are most different across the HUD and HDD conditions. The difficulties reported by the pilots may reflect interference from their relatively automatic and well-trained perception of the HDD values versus the novel HUD values. Furthermore, indices of both airspeed and ground speed are indicated on the HUD and pilots commented that they found it confusing to have these two similar values placed closely together.

The novelty of the format for speed and altitude may not convey the whole story, however. The representation of the heading information is also quite different in the HUD as compared to the HDD. In the HDD panel, heading appears as a compass (viewed from above). In the HUD, heading appears as a continuous tape, with the pilot's current heading always displayed directly forward. Despite the novelty of the heading information, the pilots did not report finding it more difficult to maintain heading or to get information from the heading tape, but tended to rate it as similar or easier to use than the compass representation of heading that they were familiar with. Importantly, the questionnaire used in the present research was sensitive to variations in the relative familiarity and useability of the various values.

Section II: Overview of the Carleton University Simulator Facility and Progress Report

2.1 Overview

The flight simulator at Carleton University is a custom version of the Networked Tactical Simulator (NTS) that has been developed by the HFE Group as part of the TAMSS initiative. As with other NTS systems, the Carleton NTS represents the flight deck, mission equipment, and physical structure of the Department of National Defence's (DND) CH146 Griffon helicopter. The Carleton simulator includes both out-the-window (OTW) and Helmet Mounted Display (HMD) capabilities. The Carleton simulator has a head tracker to support the use of the HMD. Additionally, the simulator supports the creation of synthetic environments and scenario creation via staging software.

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 pilots flying the simulator.

The Carleton NTS consists of six PCs, running Windows 2000 Professional. 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 an almost 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. As well, the INSTR1 PC hosts the custom data collection software used in the Carleton experiments. Finally, the sixth PC, the Experimenter Operating Station (EOS), is responsible for overall system control, including mission loading and unloading. As well, this PC 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. Figures 2.1 and 2.2 provide a general overview of the hardware, functionality, and communications infrastructure of the Carleton NTS.

2.2 Hardware

The following summarizes the main components of the Carleton NTS. The six PCS in the Carleton simulator are equipped with dual Pentium III 1GHz processors. Each machine has 1 GB of RAM. The machines are physically networked using a 3Com SuperStack 3 Baseline 10/100 12 port Ethernet Switch. Three NEC Model MT1055 Data Projectors are used to project generated images (using VEGA software) on 8’x 6’ screens, creating the immersive out-the-window scene. The headtracking system used is an Intersense IS-900 Virtual Workbench Tracking System. The IS-900 is a 6 degrees-of-freedom tracker, tracking both position and angular changes (X, Y, Z, Heading, Pitch and Roll). The IS-900 provides position resolution of 1.5mm in position and an angular resolution of 0.05 degrees. It is jitter-free with a position stability of 4 mm and angular stability of 0.2, 0.4 RMS. IVision Virtual Reality goggles are used as the ANVIS Head-Up Display (HUD). For a detailed depiction of the hardware configuration of the Carleton simulator, refer to Figure 2.2.

Figure 2.1 – Carleton Simulator General Overview

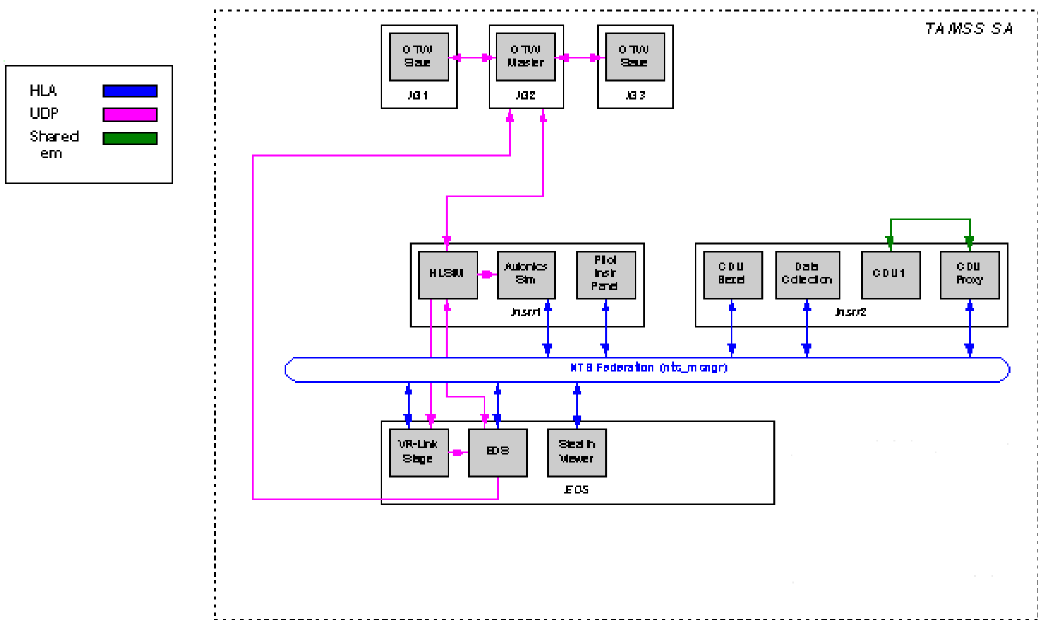

Diagram provided courtesy of the HFE Group

Figure 2.2 – Carleton Simulator Hardware Overview

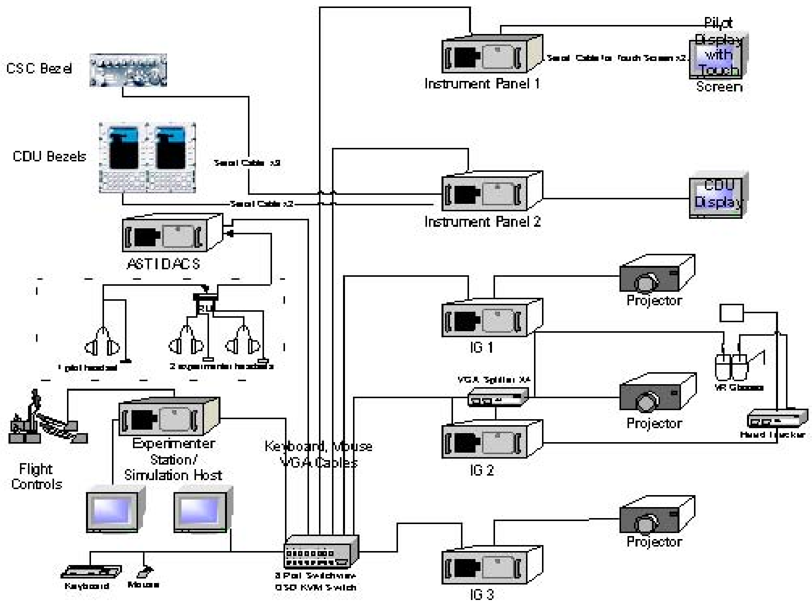

Diagram provided courtesy of the HFE Group

2.3 Software Overview

2.3.1 COTS Products

The simulator software consists of several Commercial Off-the-Shelf Software (COTS) 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 the HUD information and symbology. Vega software callbacks are used to superimpose the HUD information on the Vega scene as seen through the goggles. The API has also been used to extend Vega capabilities to handle visual experiment events generated through the experimental software.

HELISIM - Helisim, from Virtual Prototypes Incorporated, 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 CH146 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' situation 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 situation 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 STAGE’s HLA is not enabled, STAGE communicates only with the other 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.

2.3.2 Custom Code

Custom code within the Carleton simulator is used for the Experimental Operator Station (EOS). EOS is responsible for the command and control of various components as well as for the unique-to-Carleton experimental and data logging capabilities. A more detailed description of the EOS capabilities is given in the next section. Custom code is also used to develop the HMD symbology generation capabilities.

Other components that use custom code are the avionics simulation module, the pilot Head-Down Display (HDD) instrument panel, the CDU Bezel and CDUs, and the HUD symbology. The Communications software within the simulator, whether via HLA, UDP or Shared Memory is also custom code. Tools used in the development of the custom code include VAPS by Virtual Prototypes Incorporated (CDU), GLStudio (pilot head-down instrument panel and HUD symbology) by DiSTI, and VR-Link (HLA) by MÄK Technologies.

2.4 The Experimental Operator Station (EOS)

The EOS encapsulates control functions for the Carleton simulator as well as the experimental capabilities unique to the Carleton system.

2.4.1 - Command and Control Capabilities of the EOS

The control functions of the simulator are accessed via a GUI interface. The main control functions are as follows:

1. The Mission Control function opens, loads, resets, unloads and exits missions.
2. The Location function allows for console control of the aircraft position. It has a slew mode in which the operator can move the aircraft in all cardinal directions as well as change the aircrafts altitude and heading.
3. The Weather function changes atmospheric conditions such as wind direction, wind

speed and cloud cover in the OTW scene.

4. The Ownship function can be used to alter the ownship's fuel levels, communications and navigation settings.
5. The Options function currently enables the operator to change the date and time at which the mission is taking place. The Vega generated scene will accordingly adjust lighting when these are changed.
6. The Communications function enables the operator to monitor and transmit on a specified frequency via the Digital Audio Communication System (DACS). It also has an intercom capability.
7. The Freeze function allows the operator to freeze the aircraft, the scenario or both (freeze all).
8. The System Control function gives the operator some degree of remote control over the PCs in the network. It supports global Reboot, Reboot IGs, and global Shutdown capabilities.

2.4.2 - Experimental Capabilities of the EOS.

The experimental capabilities of the Carleton simulator make it different from the average flight simulator. The Carleton system has the ability to generate events, log pilots' responses to events, and log key flight-related data throughout a mission. This data can then be used to assess pilot performance, workload and situation awareness.

The experimental software has three major components: a) Experiment Scenario Generation, b) Experiment Control, and c) Data Collection. The interplay of these three components is shown in Figure 2.3.

a) Experiment Scenario Generation - The Experiment Scenario Generation creates an experimental scenario by defining a list of events that are to occur during the course of the mission. The system currently supports the generation of audio and visual events. Audio events generate a tone of specified frequency and duration using the DACS. Visual events generate an image that is displayed in Vega for a specified duration of time. The experimenter can set the onset time, timing mode (periodic or on-shot events), as well as the duration of the probe. For periodic timing, the experimenter specifies the period interval as well as the variance in interval time. For visual events, the experimenter can also specify the reference point (e.g., Head, Aircraft, or World reference), as well as the relative position to the frame center (e.g., X, Y, Z, Heading, Pitch, Roll) at which the event should appear.

Figure 2.3 – Experimental System Overview

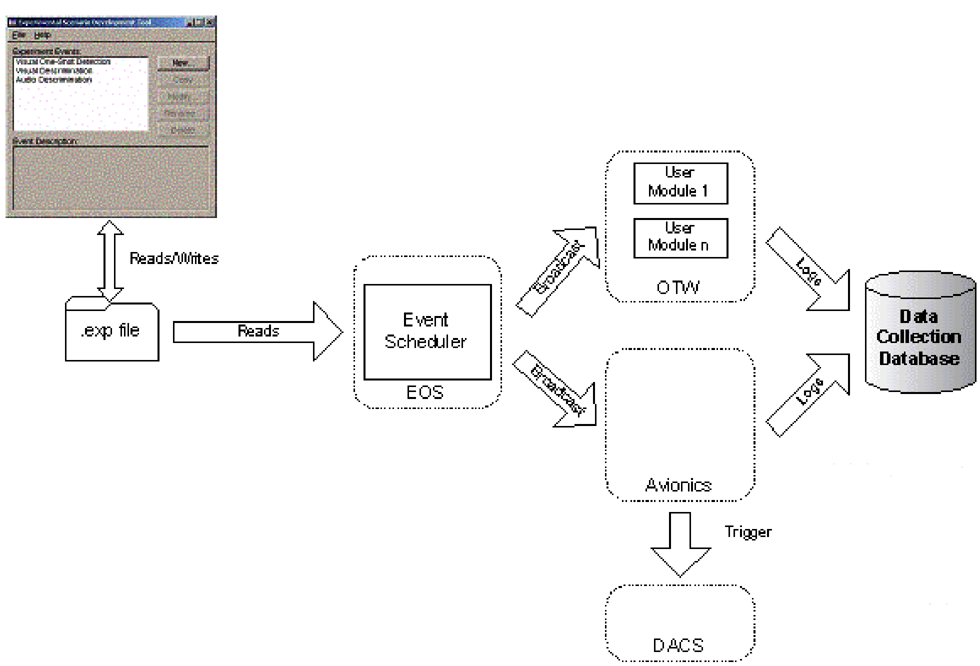

Diagram provided courtesy of the HFE Group

There are two types of tasks associated with the event, detection and discrimination, which are currently supported by the system. In the detection task, the pilot's task is to detect audio or visual stimuli and respond as quickly as possible to the stimuli, usually by pressing a button. In the discrimination task, the pilot's goal is to identify a specific object out of a range of objects, using a TRUE/FALSE type of response. The user is able to specify the number of objects to be used in the experiment as well as the weighting of TRUE to FALSE responses.

Once all the events have been specified, the experimental scenario is saved as an ".exp" file, and the experiment is ready to be launched.

b) Experiment Control - Experiment Control launches the experimental scenario and is used to initiate the data collection process once the desired ".exp" file has been selected by the experimenter. A graphical interface enables the user to select, launch and stop an experimental scenario. The EOS feeds information from the ".exp" file to an event scheduler which initiates the audio and visual events at the designated times. Experiment Control also contains a head tracker calibration utility.

c) Data Collection - Data Collection is a background process that starts automatically when the experiment is launched. The Data collection application logs the following information:

1. Session information: Session ID, Start Time, End Time, Subject Number, Trial Number
2. Audio Events: Session ID, Simulator Time (of event), Task Type, Event Duration, Truth Value, Is_Target (in discrimination task), Tone Frequency
3. Visual Events: Session ID, Simulator Time (of event), Task Type, Event Duration, Truth Value, Is_Target (in discrimination task), Object Number, Reference (Head, Aircraft, World), X, Y, Z, H, P, R

4. Button Press: Session ID, Simulator Time (of button press), Button Number Pressed
5. Headtracker Data: X, Y, Z, H, P, R (Positional and Angular information)
6. HELISIM Data: Session ID, Simulator Time (of data) plus 99 other parameters derived by HELISIM. The most important of these for experimental purposes are: Latitude, Longitude, Altitude, Speed and Heading.

The above items are logged in separate SQL tables and can be examined and extracted using a Microsoft Access application as a front-end to the database.

Because the Carleton simulator is used for experimentation, it is important to determine the amount of time delay occurring between a pilot's action or response in the simulator and the logging of this response by the Experimental software. Ideally this delay will be minimal so that the simulator mimics real-time events as closely as possible. Furthermore, the amount of time that it takes for information to pass through the system to the EOS should be consistent over time to ensure that the measures being sampled are accurate. The next section will examine the tests that have been performed by the CACR in an attempt to measure the time delays occurring within the Carleton simulator.

2.4.3 Experimental features added

In addition to the experimental features provided by the HFE group, the CACR has successfully added several new experimental features to the simulator. These include add-ons and upgrades to the HFE Group’s original applications, as well as new applications allowing for new experimental designs and measurement. This section will briefly review these features.

Freezing of the HUD - This feature allows the operator of the experiment to freeze at any given moment any of the following indications displayed on the HUD:

- Air speed

- Heading tape
- Altitude

This feature is useful for Situation Awareness (SA) experiments as the operator can record the amount of time that it takes for a pilot to notice the frozen indicators. This feature also records the time at which the freeze command was initiated, allowing the experimenters to refer to this information at a later time. This feature also provides the operator with the ability to remove and replace the entire HUD display upon command.

Freeze HDD Instruments - An application has been developed to give the operator of the experiment the ability to freeze at any given moment any of the following indications displayed on the HDD:

- Air speed
- Heading
- Radar Altitude
- Barometric Altitude
- Torque

This feature is useful for Situation Awareness (SA) experiments as the operator can indicate when or if the pilot noticed that the indicator was frozen. This application also records the time at which the freeze command was initiated.

Attitude recovery task - Although not used during Experiment 1, a complete attitude recovery task was created. The task consists of blanking the screen, placing the aircraft at a pre-configured attitude, then un-blanking the screen and passing control to the pilot. The pilot is then instructed to indicate their completion of recovery by pressing one of the cyclic buttons. During the recovery process, numerous data are recorded (in addition to aircraft attitude) including the time at which the scene was un-blanked and control was passed to pilot and the time at which the pilot indicated task completion.

This application also allows for the task difficulty to be controlled by the experimental operator. This control can be achieved by controlling/configuring the initial aircraft attitude and by controlling/configuring the turbulence at the area where the task takes place. In addition, the following task parameters can be configured by the experimental operator through the use of a task configuration table (a simple text file):

1. Air speed
2. Altitude
3. Heading
4. Pitch
5. Roll
6. Torque – This is optional in cases when inexperienced pilots are being used.
7. Turbulence – vertical air speed, horizontal air speed, period of cycles.

Cyclic button press recording and filtering - A simple filtering mechanism has been added to clear the noise that is recorded when a pilot presses and holds down the cyclic button for a long period of time. A thread was added to allow for a cyclic button press sampling rate of 5 ms. This sampling rate can be adjusted as necessary.

2.4.4 General additions and upgrades

A final addition to the Carleton simulator system is an interface for HELISIM that allows developers to fly the aircraft from the development station using a simple joystick. This interface was developed to enable the developer to fly the aircraft while using/monitoring other tools at the development station.

The addition of these experimental features will allow the CACR team to measure the SA of pilots under several new conditions (i.e., when the HUD or HDD freezes, or when they must recover after losing control of the aircraft). These measures will assist in the definition and measurement of SA.

2.5 Carleton Simulator System Timing - Evaluation and Testing

2.5.1 UDP Packet Delay Measures

The CACR engineers have taken measurements to determine the amount of time required to transfer a single UDP/IP packet between two applications running on two separate PCs. UDP/IP packets are the main data transfer mechanism used by the simulator. They are used both for direct communication between the several modules that make up the simulator system and as a transport layer for “over HLA” communication. The delay of a single small UDP packet sent between two applications running on two separate machines was measured by the CACR. This measurement was gained using loop-back methodology and was based on the internal Windows clock giving a resolution of 1ms. It was found that the measured delay in a loaded system at a steady state (while executing standard Out the Window scene) is always less than 2 ms.

2.5.2 Serial Port Loop-back delay

The delay between the writing and the reading of a single ASCII character through the PCs serial port was measured by means of an external loop-back. When a single ASCII character is written to one of the PC's serial ports, it triggers the digital scope. The digital scope is used for several timing/delay measurements in a system.

In order to perform this measurement, the Tx pin of the serial port was shortened externally with the Rx pin. Then, a Windows application was used to send a single character (8 bit) at

115600 bits/sec using the standard Windows WriteFile() call and receive the character using the standard Windows blocking ReadFile() call. The delay between the two calls was measured using the internal Windows clock with a resolution of 1ms. The measured delay between the two calls was found to be less than 2 ms. This measurement gives us an indication of the interaction delays in our system between the application layer and the hardware layer. These interactions are carried out by the Windows device drivers.

2.5.3 Vega timing (for post-draw drawing)

This measurement was taken to determine the amount of delay that occurs between the time that an object is added to the post-draw function in Vega and the time at which the object appears on the projection screen. The last stage at which Vega can execute a user code before the display buffers for the current frame are swapped and then displayed, is during the post-draw callback stage. The user can add visual objects such as the HUD symbology or any other visual objects at this stage. The CACR team measured this delay using the following process:

1. A method that blanked the scene (the display buffer) was called.
2. A method to draw a small bright (white) rectangle at the top of the scene was called.
3. A signal to trigger a two-channel digital scope was sent through the serial port to the scope.
4. Control was taken by Vega that swapped the display buffer.

This process allowed transmission the photo diode that was connected to the second channel of the digital scope through an amplifier to send a signal to the scope as soon as the bright rectangle appeared at the top of the screen. The delay between the time that an object was added as a post-draw object and the time that it took to appear at the top of the screen (in this case as a white rectangle) was 28 ms (±1ms). When the same bright rectangle was moved to the bottom of the screen, the measured delay was 44 ms (±1ms) that is, 28 ms + 1/60 Hz. It is important to note that the delay between the end of the post-draw stage (that is under the user's code control) and the time when the actual image starts to appear at the top of the screen should remain constant regardless of the amount of displayed data.

2.5.4 Cyclic button press delay

The latency between a button press on the cyclic and the time it takes to receive this response at the PCI based A/D board was measured. In the SA Experiment 1, a button press on the cyclic was used by the pilots in response to stimuli that were presented as part of the scenario. Originally the pilots' controls (including the cyclic buttons) were sampled by HELISIM at a rate of 60 Hz, meaning there was a minimum delay of 16.66 ms. A separate thread has been added by the CACR to make the sampling rate independent of HELISIM. This has allowed for a sampling rate much faster than 60Hz. In future applications, the delay will be re-measured with the addition of this new thread. Sending a character through one of the serial Tx pins and connecting it externally to one of the discrete inputs on the A/D board will gain this measure. The time difference between the call to WriteFile() and the time that a change in the state of the discrete input is sensed by the thread will be measured using the Windows clock.

2.5.5 Time Synchronization mechanism

A time synchronization mechanism to synchronize the 6 PCs in the simulator has been implemented. This mechanism consists of a timeserver that executes on one of the PCs and time clients that periodically (at ten second intervals) send time synchronization requests to the server. These time clients also receive updated time responses that are used to set their PC's internal clock.

As part of this process, half of the travel delay (the time between sending the sync request and receiving the time sync replay) is subtracted at the client side to compensate for the communication delay between the client and the server (if the measured round trip delay is longer than 4 ms the clock is not getting updated during that cycle). A UDP/IP packet with a delay of less then 2 ms was sent between the PCs to determine the degree of synchronicity between the PC clocks. The clock synchronization in the system was found to be ±2ms. This mechanism can be used to obtain accurate response measurements in the system, especially when an event is initiated by an entity executing on one machine while the response for the event is accepted by an entity executing on a different machine.

Section III: Conclusions

3.1 Cognitive Systems Engineering (CSE) Framework

Recent advances in both knowledge of human psychology and the capabilities of simulation environments support a greater role for modeling and simulation (i.e., M&S) in human factors research. The CACR Cognitive Systems Engineering (CSE) framework has been proposed as a guide for the evaluation component of the M&S process. The goal of the CSE framework is to provide general guidelines for evaluating new technologies from the perspective of how these will affect the human-machine interface.

The results of the experimental research that was conducted in the present report support the CSE framework. In particular, this research shows that converging measures of performance, workload and SA should be obtained in modelling and simulation studies, thereby allowing researchers to obtain an overall perspective that does not rely solely on a single construct or single method of measurement.

3.2 Carleton Simulator Environment

The experimental research reported in this document demonstrated that the Carleton simulator facility is an effective environment for conducting experimental tests of M&S efforts. The development tools allowed for the creation and implementation of appropriate mission scenarios (through the use of STAGE) and for the use of visual and auditory probes to objectively measure workload. The simulator communications utility was effective in allowing the experimenters to interact with the pilot. In addition, the experimenters were able to maintain awareness throughout each mission in the study through the use of the experimenter-station displays. Importantly, the pilots who participated in this experiment were quickly able to reach an acceptable level of comfort in flying the simulator. The fidelity of the simulator image generation, flight controls, communications system and the simulated avionics package was acceptable to the pilots.

The fundamental structure of the data collection and logging procedures were proven to be generally acceptable. However, further developments of the Carleton simulator are required to more fully automate data collection (including the recording of objects in the environment). In addition, detailed post-experiment analysis has revealed that the simulator produces some inconsistency in data logging that needs to be corrected and verified.

Operation of the simulator was found to be less stable than desired, resulting in occasional (and unpredictable) system crashes. Efforts are ongoing to provide for a more stable system. System stability will become increasingly critical when connecting to other models/simulators via HLA.

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ANNEX A

CSE Framework

Centre for Applied Cognitive Research
Carleton University

Cognitive Systems Engineering Framework for Modeling and Simulation in the Acquisition Process

July 11, 2002

Initial Report

Contract # 007SV-W7714-010547

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Cognitive Systems Engineering Framework for Modeling and Simulation in the Acquisition Process

Summary

Military aircraft provide a forum for the development of new aviation technology that has potentially wide application. For example, heads-up displays, a technology that is common in military contexts, are just becoming widespread in commercial aircraft. In the past, the implications of human-machine interactions were rarely explored thoroughly when new technology was added to existing systems. With the development of affordable simulation environments, however, the feasibility of testing new technologies before they are installed in aircraft has increased substantially. Savings in terms of human costs and technology retrofits are potentially enormous. Furthermore, there have been recent advances in both our knowledge of human psychology and the capabilities of simulation environments, supporting a greater role for modeling and simulation (i.e., M&S). In this report, we propose a cognitive systems engineering (CSE) framework to guide the evaluation component of the M&S process. The goal of the CSE framework is to provide general guidelines for evaluating new technologies from the perspective of how these will affect the human-machine interface. This initial report consists of three parts. Section I is an overview of the proposed CSE framework. Section II is a more detailed literature review upon which the framework was based. Section III is a comprehensive bibliography.

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Section I: Proposed Cognitive Systems Engineering Framework

I.A. Overview of the Proposed Framework

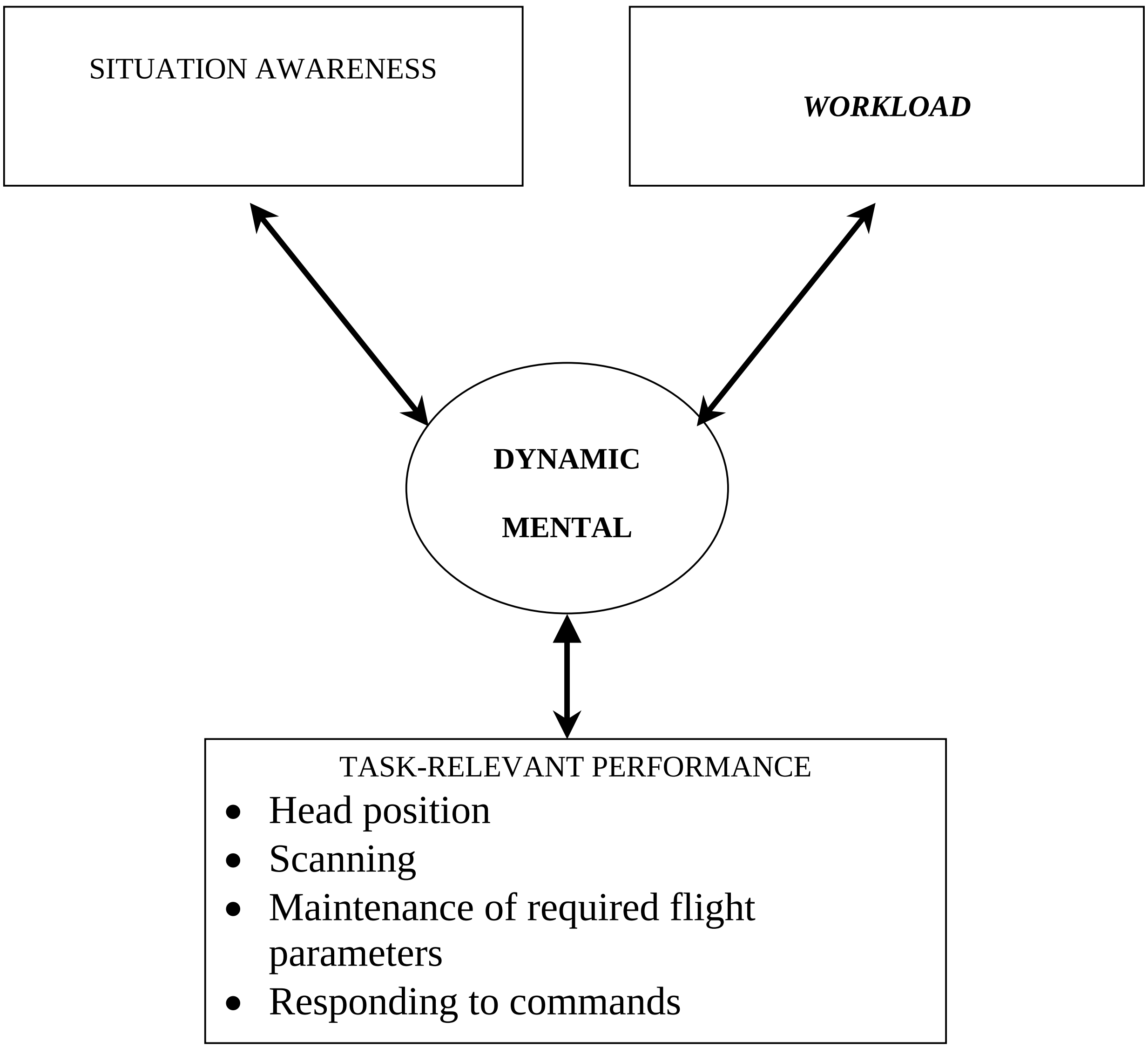
The proposed framework for evaluating new technologies in the M&S process is based on the application of a human factors approach to understanding cockpit design. In the Cognitive Systems Engineering (CSE) framework, we assume that the limitations of the human, rather than of the technology, must guide the development of new aviation systems. Pilots are extremely highly skilled operators of extremely complex machines. Improvements in technology must be designed around an understanding of the strengths and limitations of the human operator. Thus, the proposed CSE framework incorporates understanding of human cognition in a working blueprint for the design of evaluation experiments to support modeling and simulation in acquisition. As shown in Figure 1.1, the framework includes a theoretical construct, the dynamic mental model, and three empirical (i.e., measurable) constructs; situation awareness, workload, and task-relevant performance. Our review of the literature indicated that these three empirical constructs capture a large amount of the variance in the human-machine interface. The proximal goal of the CSE framework is to provide a context within which to interpret the dependent variables that are assessed in an M&S evaluation (i.e., how to assess the benefits of a new technology in a complex environment such as the Griffon CH146 helicopter). It is not intended to represent a complete model either of the human operator or of the situation, although further developments of the framework will be designed to expand the theoretical and predictive power of the model.

The central theoretical construct in the CSE framework is the dynamic mental model. It captures the notion that the human operator constantly creates and maintains an internal representation of the ongoing situation. When experimental methods are used to measure performance in an M&S evaluation, all of the measurements are inferences about the operator's dynamic mental model. The three empirical constructs, situation awareness, workload, and task-relevant performance, are assumed to provide a comprehensive (although not exhaustive) assessment of the dynamic mental model. Situation awareness, defined simply as "knowing what is going on around you" (Endsley, 2000, p. 5) is a construct that was proposed originally to capture why some fighter pilots were more successful (and therefore lived longer) than others (Spick, 1988). As discussed by Endsley (2000), SA is closely tied to knowing how to distinguish important information in the environment from less important information (selective attention), as well as the ability to quickly comprehend the importance of changes to elements in the environment.

The second empirical construct that forms the core of the CSE framework is workload. Workload is a familiar construct in aviation and has been studied more thoroughly than SA. Essentially, workload refers to the fact that humans are limited in their ability to process information and to respond appropriately. A helicopter pilot on a SAR mission who is flying with night vision goggles near the ground during a rain storm is likely to be in a situation of heavy workload. A large amount of information that changes rapidly has to be monitored and the pilot must constantly be updating his or her dynamic mental model of the environment. In contrast, a fighter pilot flying in good weather on a routine recce is probably in a low workload situation. Workload has proven to be a very useful construct for understanding changes in pilots' behaviour under different situational demands and constraints. Technology "improvements" should hypothetically decrease workload, but in practice, a technology that adds information to the pilot's environment and/or requires the pilot to perform additional tasks is more likely to increase workload. Thus, measuring changes in workload as a function of technology changes is crucial to understanding how that technology influences pilots' performance.

The third empirical construct in the framework, task-relevant performance, refers to the actions of the pilot (in relation to mission demands) that are potentially affected by the new technology. In essence, a new technology is expected to change some aspect of what the pilot knows and that knowledge will be reflected in his or her behaviour. Many other aspects of pilots' actions or behaviour might not change, however. The task-relevant performance that is relevant to any particular technological change will depend on what that technology was expected to influence. For example, the addition of a new display screen to the F-18 cockpit that has enhanced information about approaching threats should result in the pilot spending time looking at that screen and interacting with it in certain ways. Concomitantly, the F-18 pilot may spend less time using other sources of information, or may use that information differently. Thus, defining and measuring task-relevant performance is an important aspect of understanding the impact of a new technology on performance in the cockpit.

FIGURE 1.1 - CSE FRAMEWORK



In the CSE framework, the three experimental constructs (SA, workload, task-relevant performance) are second-order reflections of the pilot's dynamic mental model of the situation. Because it is impossible in practice to directly measure the contents of a human brain, use of multiple measures of the dynamic mental model is likely to provide more useful information than focusing on a single construct such as situation awareness. Furthermore, information acquired through the research process is limited by the types of measures chosen and by the underlying theoretical assumptions that guided the choice of those measures. In Section II, we present a detailed overview of the strengths and weaknesses of the constructs of situation awareness and workload. The bottom-line conclusion is that any single measure is unlikely to provide sufficient information to allow for general conclusions about the impact of a new technology on the crew.

Because it is impossible to directly measure the dynamic internal model (as it is not possible to directly measure "memory" or "thinking"), all measures we can use are behavioural in the sense that the pilot or crew must perform some action that is then assessed. For example, a subjective assessment of situation awareness requires that the pilot make a judgment or provide an evaluation. Head position could be used as an index of where the pilot is attending. Altitude maintenance could be used as an index of the pilot's adherence to the flight plan. In the case of SA, the simulation can be frozen and then pilots can be asked to report instrument information (such as altitude), or to make a prediction about the trajectory of enemy planes (i.e., bogies). Their answers to such queries are assumed to reflect their interrogation of their dynamic mental model (i.e., memory for the current location of bogies and knowledge about what those bogies are likely to do). In general, the researcher assumes that the behavioural responses or actions can be used as an index of the pilot's knowledge or mental processes.

Because of the complexity and multi-dimensional nature of the dynamic mental model, any single construct or any single measure of a construct is unlikely to capture sufficient information about the impact of a new technology. Instead, we propose that the CSE evaluation should include at least one, and preferably multiple measures of each of situation awareness, workload, and task-relevant performance. Use of multiple measures will allow for a richer and more accurate answer to the question "how does the new technology affect the human-machine interaction"? Below, we provide a detailed example of a previous M&S evaluation carried out by the CACR (in conjunction with CMC Electronics) that illustrates the importance of having multiple constructs and measures. Although this evaluation was conducted prior to the development of the CSE framework, it has characteristics that are consistent with the CSE approach that we are recommending.

I.B - Example: Direct Voice Input for the CH146 Griffon Helicopter

In designing and selecting measures (whether of performance, SA, or workload), it is important that these be constrained both by the specific situation (e.g., the CH146 environment) and the nature of the technological upgrade. Thus, the first step in an M&S evaluation is to do a rational analysis of how the technology is *expected* to influence pilot's behaviour. In the evaluation of direct voice input (DVI) for the Griffon, heads-up time was identified as a key variable that should be affected when pilots' were given DVI capabilities. Furthermore, heads-up time is an ecologically valid measure, because pilots are instructed and trained to spend as much time as possible looking outside of the aircraft. The DVI interface that was designed for the Griffon allowed the non-flying pilot to use voice commands for certain common actions that normally would be entered on the onboard computer (the CDU) that is located between the seats in the cockpit. For example, pilots could change the radio frequency by saying "SET RADIO 1

TO 121.5" instead of typing a series of commands on the CDU. Using a voice command meant that the non-flying pilot could potentially keep his or her eyes on the outside world. Because pilots are instructed to look outside the cockpit as much as possible, any increase in heads-up time would be a reasonable and logical outcome of the change from manual input to DVI. Heads-up time was measured in this evaluation by tracking the pilots' head position throughout the simulated recce missions, and then comparing the total heads-up time in the DVI condition to that in the manual input position. As predicted, heads-up time increased with DVI relative to the manual condition (by an impressive 42%), indicating that the technology change had at least one of the expected and desirable outcomes on pilots' behaviour.

Heads-up time is not the whole story, however. Although the CSE framework shown in Figure 1 had not been developed when the DVI study was planned, the researchers who conducted the evaluation recognized that multiple measures of behaviour would provide a more complete picture of the impact of DVI on the human-machine interaction. In particular, introduction of DVI to the Griffon cockpit had a variety of other potential effects. First, DVI had the potential to change the CRM in that the flying pilot now had the opportunity to interact with the CDU, whereas in the manual input situation only the non-flying pilot can enter commands on the CDU. So the workload or performance of the flying pilot might also be affected by the new technology. Second, if having to look at the CDU to enter commands was a workload-intensive activity for the nonflying pilot, then DVI might decrease his or her overall workload. Other aspects of the pilots' task performance, however, were unlikely to be affected in the types of missions that were flown.

Workload was measured in this experiment using detection of auditory and visual stimuli (i.e., targets) by both pilots. The targets (auditory tones or visual flashes in the external scene) were presented randomly in the course of the simulated missions. Pilots were instructed to respond as quickly as possible when they detected a target by pressing a key. Target detection as an index of workload has been used extensively and thus has both empirical and theoretical support. Essentially, the speed with which the pilot responds to the target can be used as a measure of his or her available mental capacity. In the DVI experiment, the workload of the non-flying pilot was less in the DVI condition that in the manual condition, suggesting that the DVI facility was likely to result in improved pilot performance. Importantly, however, the workload of the flying pilot increased significantly in the DVI condition. Even though the flying pilots infrequently used the DVI capability, the incremental change to their responsibilities was evident in the workload measure. In accord with the CSE framework, DVI had a significant impact on the flying pilot's dynamic mental model. This unexpected finding speaks to the complexity of changing the CRM as a function of the technological upgrades and to the importance of measuring multiple aspects of the overall pilot activities.

Situation awareness was not directly measured in the DVI experiment. Instead, it was inferred that SA would be better as heads-up time increased and workload decreased (Vidulich, 2000). Because inclusion of DVI capability resulted in a substantial increase in heads-up time and a decrease in workload for the nonflying pilot, it was concluded that the SA of nonflying pilots was likely to improve given DVI capabilities. In contrast, the SA of the flying pilot may be worse in DVI conditions, at least when they are allowed to use the DVI for commands that normally would be handled by the nonflying pilot. In summary, even though the DVI was conducted before our formalization of the CSE framework, it provides a concrete example of how multiple measures and converging evidence is necessary in the CSE process. Actual assessment of situation awareness would have provided an even more comprehensive picture of how DVI influenced cockpit activities.

I.C - Implications of the CSE Framework for Cockpit Research

Our review of the literature on cockpit research shows that workload, SA, and task-relevant performance capture a substantial amount of variability in the human-machine interaction. Workload refers to the cognitive effort required by the pilot, SA is the pilot's perception of events and integration of those events into a coherent understanding of the situation, and task-relevant performance captures the behaviours associated with the interactions between the human and the machine. Direct evaluation of performance provides important information about the pilot-system interface at the level of perceptual-motor coordination and thus allows for the evaluation of direct interaction with the system through systems control. Both SA and workload represent an aspect of the pilot-system interaction that does not directly reflect performance. Therefore, under some conditions, we should not expect a high correlation between SA or workload and the overall pilot-system interaction. Good SA does not always lead to good performance and high workload does not always predict poor performance. Nevertheless, these constructs are related and in many situations, good SA will predict good performance. More generally, the CSE framework emphasizes the importance of multiple interacting aspects of pilot behaviour.

Furthermore, the CSE framework makes an important distinction between the concepts that are being measured as part of the pilots' behaviour and concepts that are being measured as the underlying cognitive mechanism. One of the major problems in properly defining SA is a lack of distinction between SA as the measured construct and SA as the pilot's internal representation of the world (e.g., Endsley, 2000). SA originated as a description of behaviour (i.e., that some pilots are much more skilled than other pilots) but has often been used in the literature as the explanation for good performance (e.g., because the pilot has good SA, she performed well). This confusion between SA as an explanation and SA as a description needs to be avoided so that SA does not become circular and therefore an empty concept (Flach, 1995). .

A central tenet of the CSE framework, therefore, is that the human-machine interaction in the cockpit is too complex for a single concept to provide sufficient information to evaluate the impact of an interface on pilots' overall behaviour. By distinguishing among SA, workload, and performance and the underlying mental representation (the dynamic mental model), researchers can more clearly operationalize the concepts for empirical purposes. Research that is conducted within the CSE framework should allow for comprehensive and valid assessment of human factors aspects of new aviation technology.

Section II: Definitions and Literature Review

Reviews of situation awareness, workload, and related issues in cockpit research were done with various databases, including PsycINFO, Social Science Citation Index (SSCI), CISTISource and Web of Science. Pertinent references from other sources (e.g., conference proceedings of the Aviation Psychology conference) were also included. The edited bibliography of articles gathered via these searches is included at the end of this initial report. A reference list that includes those cited in the body of this report is also included. Our goal with the review portion of this report is to provide a critical overview of these psychological constructs, and to give recommendations that are pertinent to modeling and simulation activities relevant to the CH146. A third section (to be added in the final version of the report) will include descriptions of the results of Experiments 1 through 3, where the CSE framework was used to develop and implement the human factors component of the M&S process.

II.A. - Situation Awareness

II.A.1. - Defining Situation Awareness

Situation awareness, defined simply as "knowing what is going on around you" (Endsley, 2000, p. 5) is a construct that was proposed originally to capture why some fighter pilots were more successful (and therefore lived longer) than others (Spick, 1988). As discussed by Endsley (2000), SA is closely tied to knowing how to distinguish important information in the environment from less important information and to the ability to quickly comprehend the importance of changes to elements in the environment (Adams, Tenney, & Pew, 1995; Durso & Gronlund, 1999; Endsley, 1995; 2000; Sarter & Woods, 1995). Spick (1988) suggests that an important aspect of what made the aces better than the average pilot was their superior judgment about when to either engage in a fight or disengage in one that was not going well. Hence, SA represents pilots' ability to keep track of objects such as enemy aircraft in the environment and to estimate the probability of success in a given situation.

Situation awareness is appealing because it seems intuitively obvious that successful completion of missions requires that pilots are aware of the status of the aircraft and the various elements of the situation. It has proven difficult, however, to define what SA is for empirical purposes. Researchers offer different perspectives on what constitutes SA. This lack of a clear definition has made it difficult to establish a coherent framework for conducting SA research. Furthermore, researchers disagree as to whether or not SA is not a unitary phenomenon (Pew, 2000; Sarter & Woods, 1991). Researchers face a variety of difficulties in defining SA. First, SA encompasses a wide variety of factors such as keeping track of objects in the environment, attending to relevant information, and pilot's knowledge of the mission. Second, the elements of the situation that are relevant vary considerably depending on the nature of the mission and the aircraft. For example, although altitude tracking is critical to a helicopter pilot attempting to maintain a hover over the ocean, altitude tracking is not critical to a fighter pilot who is engaged with an enemy aircraft. These complexities have made it difficult to produce a single, definitive description of SA.

One commonality across different descriptions of SA is an emphasis on the underlying cognitive mechanisms that determine SA and that are common to different situations (Adams et al., 1995; Endsley, 2000). Endsley (1988) defined SA as: "…the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the future" (1988, p. 97). Endsley included three levels within the construct of SA: perception, comprehension and projection (Endsley, 1995, 2000). Endsley's model will be considered in some detail because it is the most widely cited description of the construct of SA.

Level 1 SA is the operator's perception of the current status of the environment. For instance, in a cockpit environment, Level 1 SA includes the perception of the various indicators on the display such as the altitude indicator, heading, and relative position. Level 1 also includes the perception of objects in the environment such as mountains, trees, other aircraft, and warning lights. Level 2 SA refers to how the situation is understood (i.e., how the various elements that are perceived at the earlier level are integrated and comprehended). At Level 2 SA the various elements perceived in the situation are integrated in light of the pilot's goal and the requirements of the task. At this level the pilot forms a holistic picture of the environment that combines the individual elements with stored knowledge of these elements. Level 3 SA refers to the pilot's ability to predict future status of the situational elements and to anticipate the requirements of the operating system. This is the highest level of SA and is based on the elements of both Levels 1 and 2.

Endsley (1995) proposed a theoretical model of SA. In her model Endsley describes SA as a dynamic mental model of the world that is determined by various cognitive factors such as attention, working memory, and prior knowledge. Unfortunately Endsley's model is far too complex to generate testable hypotheses or guide experiments. Also, it is not clear within the model whether measured SA is the behaviour of the pilot or the underlying cognitive state (Flach, 1995). Furthermore, Endsley emphasizes that SA as a cognitive state that is independent from performance. Therefore, performance measures often play a small role in cockpit evaluations unless specifically defined as being an indirect measure of SA. In summary, although Endsley's model has had considerable impact on the field of aviation psychology, it functions more as a way of describing the human-machine interaction, rather than as a framework for developing M&S research.

II.A.2 - Measuring Situation Awareness

In combination, Pew (2000) and Vidilich (2000) proposed five broad categories of measurement that have been used in research on situation awareness. As shown in Table 2.1, these include verbal protocols, awareness queries, subjective assessments, performance assessments, and situation manipulations. Pew (2000) provides the more comprehensive taxonomy of SA measures, however, Vidulich (2000) noted that researchers have often inferred SA from performance, rather than measuring it directly. In accord with the proposed CSE framework, measuring only SA or only workload is likely to be restrictive. The overlap between SA and performance noted by Vidulich supports our view that multiple constructs and multiple measures of these constructs are most likely to provide a comprehensive overview of the human-machine interaction.

Table 2.1

Taxonomy of Measurement for Situation Awareness (after Pew, 2000, and Vidulich, 2000)

Our terminology	**Pew's Terminology [Vidulich][a]**	**Description**
Verbal Protocols	Verbal protocols	Pilots provide online or immediately retrospective think-aloud descriptions of their mental processes
Situation Manipulations	Direct system performance measures	During the simulated mission, the experimenter: (a) introduces either an anomaly, or some kind of subtle scenario manipulation that the pilot is expected to detect if they have good SA (b) introduces disruptions that pilots must recover from (e.g., freeze the simulation, then introduce an offset to the heading) (c) introduces anomalous data or instrument readings and observes pilots' responses
Awareness Queries*	Direct experimental techniques [memory probe measures]	Pilots respond to queries or probes collected when a simulation is frozen (e.g., best known method is SAGAT; Endsley [2000])
Subjective Assessment*	Subjective measures	Self-assessments (usually after the mission has finished), expert judgments of pilot SA, peer ratings, supervisor or instructor ratings
Performance Assessment*		Experimenter makes an inference about effects of a technology on SA by evaluating changes in performance

[a] terminology used by Vidulich (2000) if it is different than that used by Pew (2000)

* categories included in Vidulich (2000) meta-analysis.

II.A.3 - Summary

SA represents how well the pilot perceives the situational elements and integrates them into a coherent understanding of the situation. Measurement of SA can show how a well-designed system supports the pilots’ cognitive needs whereas a poorly designed system may result in pilots lacking a coherent understanding of their surroundings (Jones & Endsley, 1996). However, although SA provides important insight into some aspects of the pilot-system interaction, other aspects may be neglected. For example, by focusing on measuring a pilot's understanding of the situation, some critical aspects of behaviour may be overlooked. For example, perceptual-motor coordination that is reflected in how well the pilot maintains a route or reacts to stimuli in the environment is an important part of the overall adaptation to the requirements of the cockpit system. Thus, measurement of SA needs to be supplemented by other sources of information. The proposed CSE framework would help researchres to capture more of the variance involved in pilot-system interaction as compared to measuring a single construct. Thus, the goal of the CSE framework is to guide future research in this domain based on the assumption that multiple measures of three central constructs (i.e., SA, workload, and task-relevant performance), will give a reasonably complete perspective on how any given technology influences human responses in the cockpit.

II.B. - Workload

II.B.1 - Defining Workload

The concept of mental workload has been used in the aviation community to capture the relations among task difficulty, limitations in pilots’ cognitive abilities, and performance (Flach & Kuperman, 2001; Wickens, 2001). Workload is an index of how much cognitive effort is required by pilots as they interact with a given system. Measuring workload is particularly relevant to cockpit research where the challenge is to reach a balance between the quantity of information provided and the pilots' capacity to process that information. In general, as more effort is required from the pilot for a given task, fewer cognitive resources are available for accomplishing other tasks. High workload is associated with emotional stress, fatigue, and decrements in performance (Hart & Wickens, 1990; Tsang & Wilson, 1997).

Workload has been defined as: "a hypothetical construct that represents the cost incurred by a human operator to achieve a particular level of performance" (Hart & Staveland, 1988, p.140). This definition of workload is framed within the resource model of information processing such that workload represents the relation between the availability of cognitive resources and the demands of the task (Wickens, 1991). Within this model, performance decrements occur when tasks that are being performed simultaneously require the same cognitive resources. This resource-based definition of workload is consistent with a large literature on the relations between mental effort and performance in a wide range of cognitive tasks. In aviation research, however, a disadvantage of this definition of workload is that it does not distinguish between how the pilot experiences the level of task difficulty and the actual impact it has on performance.

In the domain of aviation, researchers have placed more emphasis on the pilot's experience of workload (i.e., subjective workload) than on objective workload (i.e., performance trade-offs) by measuring physiological responses and asking pilots to rate their perceived workload (Hart & Wickens, 1990; Wickens, 1999). The focus on how pilots experience workload reflects the finding that, in highly trained pilots, high workload does not necessarily reflect poor performance (Vidulich & Wickens, 1986; Yeh & Wickens, 1988). Nevertheless, if the pilot experiences a task as demanding (i.e., high in workload), he or she may become fatigued and mission effectiveness may be compromised. A common pattern seen in workload research is that performance is stable for a long time and then suddenly declines. Initially, researchers assumed that the performance decrement reflected a sudden increase in workload that exceeded the pilots' cognitive resources. However, subjective ratings and physiological measures showed that pilots actually experienced a steady increase in workload up to the point of the performance decrement (Andre, 2001).

In summary, both the objective workload (i.e., trade-offs between performance and effort) and subjective workload (i.e., the pilots' perception of workload) are important aspects of the human-machine interface in research on aviation. However, although research suggests that workload measures are a valuable tool in aviation research, they have not been used consistently because there is no consensus in how workload should be measured (Flach & Kuperman, 2001; Wickens, 2001).

II.B.2 - Measuring workload

Numerous measures have been proposed to evaluate workload in the cockpit. The proposed measures of workload can be classified into four broadly defined categories; primary-task measures, secondary-task measures, physiological measures, and subjective ratings (Bortolussi, Kantowitz & Hart, 1986; Casali & Wierwille, 1984; Hart & Wickens, 1990; Wickens & Hollands, 1999).

Primary-task measures. Measuring performance on the primary task (i.e., the task required by the system in question) allows for the assessment of whether the task causes boredom and hence less vigilance over time, whether performance is stable over time, and at what point performance breaks down. However, performance on a primary task is rarely used to evaluate workload as it tends not to co-vary with pilots' experience of workload. Therefore, poor performance may or may not reflect demands on resources (Yeh & Wickens, 1988). Thus, primary task performance can be considered a baseline measure, but it is only directly indicative of workload when cognitive resources are exceeded and performance begins to break down.

Secondary- task measures. When pilots simultaneously perform two tasks, the primary task is the central aviation task (e.g., hovering) whereas the secondary task is added by the researcher to reflect the availability of cognitive resources. For example, in the DVI evaluation reported by Herdman et al. (2001), the primary task was to complete the mission whereas the secondary task was to detect the auditory and visual targets. The pilot is instructed to perform as well as possible on the primary task and allocate any leftover resources to the secondary task. As the primary task becomes more difficult, fewer resources are available for performing the secondary task and thus the focus is on decrements in performance on the secondary task. Common secondary tasks used to evaluate workload are: a) a rhythmic tapping task where the pilot must produce a finger or a foot tap at a constant rate, b) random number generation where the pilot must randomly generate numbers, and c) reaction time to probe stimuli (e.g., Herdman et al., 2001).

Secondary task measures have been used frequently to evaluate workload. However, the method has some limitations. First, when the primary task reaches a certain level of difficulty the pilots may simply abandon the secondary task. Second, research on workload using secondary measures has shown that different types of secondary measures will be interfered with selectively by the primary measure. For example, tapping is more likely to interfere with a spatial primary task than with a verbal primary task (Baddeley & Logie, 1999). This selective interference means that the workload differences caused by the primary task may be underestimated if the primary and secondary tasks require different processing resources (see

Hart & Wickens, 1990). Third, introducing a secondary task to the pilot may be intrusive for the pilot. Despite these limitations, however, secondary task measures provide a very useful objective index of pilot workload. Furthermore, the use of the dual-task method is a well-established way of indexing cognitive demands in the wider literature (Baddeley & Logie, 1999) and thus considerable research can be accessed to develop and interpret the results of workload research in the aviation field.

Physiological measures. Physiological measures of workload include heart rate, eye blink rate, pupil diameter, respiration frequency, blood pressure, and electrical activity of the brain. Use of these measures is based on the assumption that, for example, an increase in heart rate or respiration reflects a concomitant (but not necessarily conscious) increase in workload. One advantage of physiological measures is that they are less obtrusive than subjective ratings or secondary task measures. Furthermore, measurement of physiological responses provides information about the pilots' emotional and physical activation during the course of a task as well as their processing time and cognitive load. Researchers have shown that physiological measures are a reliable indication of workload (Bortolussi, Kantowitz & Hart, 1986; Casali & Wierwille, 1984). However, the main limitation of physiological measures is that they are indirect indices of how the pilot actually experiences the workload. Furthermore, physiological measures may not relate directly to performance. [2]

Subjective evaluation. Subjective ratings of workload have been used most frequently in research on aviation. They have the advantage of directly measuring the pilots' experience of workload in terms of cognitive cost and attentional resources (Hart & Wickens, 1990). Two

[2] Although visual scanning or other measures of behavior are sometimes classified as "physiological measures", in the CSE framework these would be considered as elements of "task-relevant performance". Visual scanning is a very indirect measure of physiological processes.

questionnaire measures are commonly used in evaluating the pilots' experience of workload, the NASA task load index (NASA TLX; Hart & Staveland, 1988) and the subjective workload assessment technique (SWAT; Reid & Nygren, 1988). The NASA TLX assesses workload on five 7-point scales; mental demand, physical demand, temporal demand, performance, effort, and frustration level. The SWAT assesses workload on three 3-point scales; time load, mental effort, and stress.

Subjective ratings of workload are widely used. Subjective ratings are relatively easy to administer and have minimal impact on pilots' ongoing behaviour because they are typically given after a task is completed. These measures are limited, however, because they are rarely used to index online workload (i.e., workload that is experienced while the pilot is doing the task) and because they are subjective. As with any measure that requires pilots to introspect on their behaviour, there are always questions about whether such measures are reliable (i.e., are the measures consistent? Can pilots' calibrate their responses across tasks?) and valid (i.e., do the responses actually reflect workload?; Wickens, 1999). Furthermore, rating scales are limited in that they will only tap into a subset of factors that may be relevant to the overall experience of workload (Hart & Wickens, 1990). More research in which subjective measures are collected in conjunction with objective measures is needed to probe the validity of these assessments.

II.B.3 - Summary

In aviation research, assessment of workload is important for evaluating the adequacy and feasibility of the human-machine interaction. High workload may reflect a poorly designed system that puts an unnecessary load on the pilot. For example, an instrument layout in the cockpit that requires longer gaze time by pilots than an alternative layout may increase pilot workload. Similarly, Herdman et al. (2001) found that the addition of a DVI system to the

CH146 cockpit resulted in an increase in the workload of the flying pilot (as indexed by the secondary task performance). Hence, it is crucial to measure pilot workload in any technology evaluation. Although four categories of workload measurement have been described (i.e., primary-task measures, secondary-task measures, physiological measures and subjective ratings), multiple measures have rarely been used in the same studies. Furthermore, workload measures have not been used consistently in cockpit research (Wickens, 2001). As with performance and situation awareness, converging measures of workload are most likely to provide a comprehensive understanding of the impact of technology on the cockpit activity.

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ANNEX B

Pilot Questionnaires

TAMSS Experiment 1 **Participant ID: __________**

Background Information

1. Age: ___________ (in years)
2. Years in CF: ___________
3. Years as a pilot: ________
4. Handedness: ____left OR ___ right

Please Estimate your flight thime in each category:

Type of Flight	**Estimated time (in hours)**
1. Total flight time	
2. Total rotary wing	
3. Total Griffon	
4. Total NVG	
5. Total NVG with HUD	
6. Time spent using a flight simulator	

Specify the type of simulator experiences that you have had:

____

____

____

TAMSS Experiment 1 **Participant ID: _______________**

HUD vs. no-HUD comparison
Rate the impact of having a HUD as compared to NO HUD on your experiences in the simulator. Circle your response for each item. A rating of '4' means there was no difference between the HUD and no-HUD conditions.

	COMPARISON							
	HUD much better than no-HUD			No difference			**No-HUD** much better than HUD	
1. Overall situation awareness	1	2	3	4	5	6	7	NA
2. Awareness of heading	1	2	3	4	5	6	7	NA
3. Awareness of altitude	1	2	3	4	5	6	7	NA
4. Awareness of airspeed	1	2	3	4	5	6	7	NA
5. Awareness of spatial orientation	1	2	3	4	5	6	7	NA
6. Awareness of activity on the ground	1	2	3	4	5	6	7	NA
7. Awareness of activity in the air	1	2	3	4	5	6	7	NA
8. Awareness of aircraft systems	1	2	3	4	5	6	7	NA
9. Cross checking relevant instruments/symbology	1	2	3	4	5	6	7	NA
10. Using information from the scene to control the aircraft	1	2	3	4	5	6	7	NA
11. Eyes-out time	1	2	3	4	5	6	7	NA
12. Low-level flight	1	2	3	4	5	6	7	NA
13. Low-level maneuvering	1	2	3	4	5	6	7	NA
14. Maintaining airspeed	1	2	3	4	5	6	7	NA
15. Maintaining heading	1	2	3	4	5	6	7	NA
16. Maintaining altitude	1	2	3	4	5	6	7	NA

TAMSS Experiment 1
Mission Assessment

Participant ID	
Date	
Time	
Mission number	
Scenario Code	
Condition	HUD no-HUD

Instructions

If you have additional comments about any question or item, please write these on the back of the corresponding page.

M1. Rate how frequently you looked down at the instrument panel during this mission.

never	rarely	sometimes	often	very often

M2. Rate how well you performed each of the following tasks during this mission. Circle N/A if the item was not applicable to this mission.

	PERFORMANCE							
Task	very poor			adequate			very good	
Finding waypoints	1	2	3	4	5	6	7	NA
Maintaining correct heading	1	2	3	4	5	6	7	NA
Maintaining correct altitude	1	2	3	4	5	6	7	NA
Maintaining correct airspeed	1	2	3	4	5	6	7	NA
Cross checking relevant instruments/symbology	1	2	3	4	5	6	7	NA
Using information from the external scene to control the aircraft	1	2	3	4	5	6	7	NA

M3. Rate the difficulty of each of the following tasks during the mission. Circle N/A if the item was not applicable to this mission.

	DIFFICULTY							
Task	very easy			moderate			very difficult	
Finding waypoints	1	2	3	4	5	6	7	NA
Maintaining correct heading	1	2	3	4	5	6	7	NA
Maintaining correct altitude	1	2	3	4	5	6	7	NA
Maintaining correct airspeed	1	2	3	4	5	6	7	NA
Cross checking relevant instruments/symbology	1	2	3	4	5	6	7	NA
Using information from the external scene to control the aircraft	1	2	3	4	5	6	7	NA

M4. Rate the difficulty of getting (reading) information from each of the following sources during this mission. Circle NA if not applicable to this mission.

	DIFFICULTY							
	very easy			moderate			very difficult	
Heading	1	2	3	4	5	6	7	NA
RAD Alt	1	2	3	4	5	6	7	NA
Airspeed	1	2	3	4	5	6	7	NA
Attitude	1	2	3	4	5	6	7	NA
External Scene	1	2	3	4	5	6	7	NA

M5. Rate your awareness of the following during the mission. Circle NA if not applicable to this mission.

	AWARENESS							
	very low			moderate			very high	
Overall Situation Awareness	1	2	3	4	5	6	7	NA
Heading	1	2	3	4	5	6	7	NA
RAD Alt	1	2	3	4	5	6	7	NA
Activity on the ground	1	2	3	4	5	6	7	NA
Activity in the air	1	2	3	4	5	6	7	NA
Airspeed	1	2	3	4	5	6	7	NA
Attitude	1	2	3	4	5	6	7	NA
Spatial Orientation	1	2	3	4	5	6	7	NA
Environmental Events	1	2	3	4	5	6	7	NA
Aircraft Systems	1	2	3	4	5	6	7	NA

M6. Rate your workload during this mission. Circle NA if not applicable during this mission.

	WORKLOAD							
	very low			moderate			very high	
Between waypoints	1	2	3	4	5	6	7	NA
At waypoints	1	2	3	4	5	6	7	NA
When reporting activity	1	2	3	4	5	6	7	NA
Overall	1	2	3	4	5	6	7	NA

At any point, did you find that your workload was very different (e.g., much higher or lower) than across the mission as a whole? YES or NO

If yes, please elaborate:

____

____

____

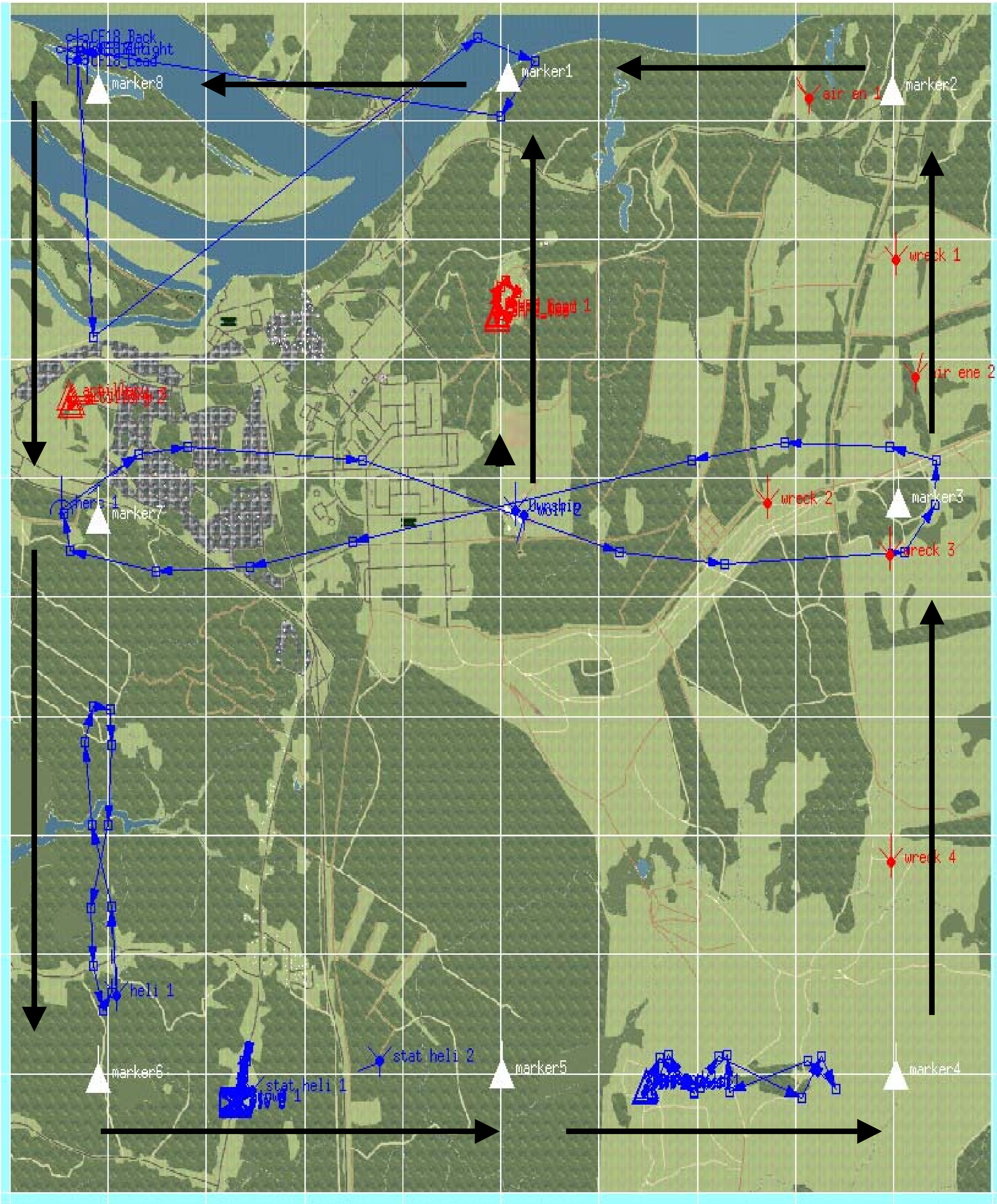
____

____

____

____

ANNEX C
Sample Mission Routes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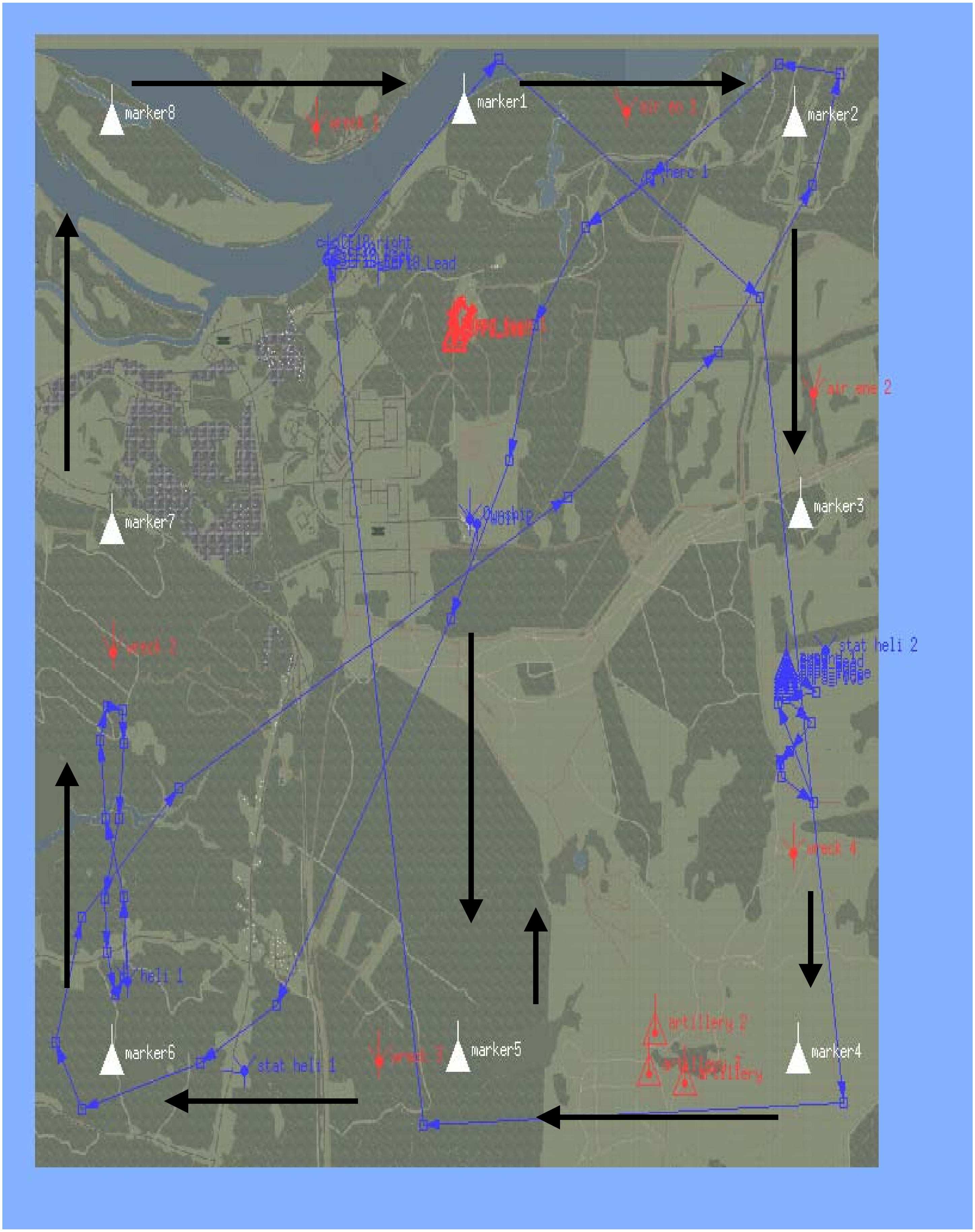
stat heli 1
marker5
marker4



marker8
marker1
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marker7
Ownship
stat heli 2
stat heli 1
heli 1
wreck 2
wreck 4
artillery 2

Annex F – Report 3: Experiment 2

Centre for Applied Cognitive Research

Carleton University

Situation Awareness, Performance, and Workload in Simulated Flight:

The Impact of an ERSTA-Like System on the CH-146 Mission Commander

TAMSS SA PROJECT

Report on Experiment 2

Dr. C.M. Herdman

25 March 2003

Contract Serial No. 007SV-W7714-010547

Situation Awareness, Performance, and Workload in Simulated Flight:

The Impact of an ERSTA-Like System on the CH-146 Mission Commander

TAMSS SA

Report on Experiment 2

Dr. C.M. Herdman

31 March 2003

Contract Serial No. 007SV-W7714-010547

Prepared by

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31 March 2003

Contract Serial Number 007SV-W7714-010547

Prepared by: ________________________
C.M. Herdman
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Principal Investigator

Prepared with the assistance of: K.R. Johannsdottir, J. Jarmasz, C. Michalyna, D. Bleichman, and S. Dunlay

This study, approved by Carleton University's Human Research Ethics Committee, was conducted in conformity with the Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans.

Situation Awareness, Performance, and Workload in Simulated Flight: The Impact of an ERSTA-Like System on the CH-146 Mission Commander

Centre for Applied Cognitive Research
March 31, 2003

Executive Summary

As part of the Department of National Defence (DND) Tactical Aviation Mission System Simulation (TAMSS) Situation Awareness initiative, the Centre for Applied Cognitive Research (CACR) at Carleton University has proposed a Cognitive Systems Engineering (CSE) framework to be used as a guide for conducting and interpreting evaluations in M&S programs. The present document is a report on Experiment 2 (E2) of the TAMMS SA program. Experiment 2 of the TAMSS SA program had two major activities. The first activity was to integrate the DND CH-146 ERSTA-like system with the simulator facility at the Carleton University Centre for Applied Cognitive Research (CACR). The ERSTA modelling and integration activity is to be extended into the third and final TAMSS SA experiment. Thus, the report on this activity will be presented as part of the Experiment 3 report. The second major activity in Experiment 2 was to conduct a study to evaluate the impact of the prototyped digital moving map and an ERSTA-like sensor capability on CH-146 Griffon aircrew. The particular focus of the experiment was on how ERSTA-like system affects the performance, situation awareness and workload of the CH-146 Mission Commander (MC). This experimental activity is reported in the present document.

REVISION PAGE

REVISION LETTER	PAGES AFFECTED	DATE	APPROVAL

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LIST OF FIGURES

Situation Awareness, Performance, and Workload in Simulated Flight: The Impact of an ERSTA-Like System on the CH-146 Mission Commander

This document is a report on Experiment 2 (E2) of the TAMMS SA program. This experiment had two major activities. The first activity was to integrate the DND CH-146 ERSTA-like model[1] with the simulator facility at the Carleton University Centre for Applied Cognitive Research (CACR). This activity included (a) modifying the extant DND ERSTA model to reflect the core mapping and sensor capabilities of the ERSTA system that is anticipated for the CH-146 Griffon, (b) designing and implementing moving map and sensor display interfaces for the cockpit, (c) making the ERSTA-like system compliant with High-Level Architecture (HLA) specifications, and (d) linking the HLA-compliant ERSTA-like model with the CACR Griffon simulator. The ERSTA modelling and integration activity is to be extended into the third and final TAMSS SA experiment. Thus, the report on this activity will be presented as part of the TAMSS Final report.

The second major activity in Experiment 2 was to conduct a study whereby the Cognitive Systems Engineering (CSE) framework that has been proposed by the Carleton University CACR was used to evaluate the impact of the prototyped ERSTA-like digital moving map and sensor capability on CH-146 Griffon aircrew. The particular focus of the experiment was on how the ERSTA-like system affects the performance, situation awareness and workload of the CH-146 Mission Commander (MC). This experimental activity is reported in the present document.

1 Introduction

1.1 Goals

The experimental goals were to extend the evaluation of the Cognitive System Engineering (CSE) framework proposed by the CACR for evaluating the impact of novel technology on aircrew in the CH146 Griffon helicopter. This involved (a) integration of an emulation of the DND CH-146 ERSTA-like system into the CACR simulator using HLA protocol, (b) development of realistic tactical scenarios, (c) further development of the data collection capabilities of the CACR simulation facility and (d) further development of the questionnaire battery used for assessing workload.

In this experiment, aircrew consisting of a Flying Pilot (FP) and a Mission Commander (MC) completed a series of zone recce missions. Of primary interest was how digital moving map and ERSTA-like sensor capabilities affect the performance, situation awareness and workload of the CH-146 MC while completing these missions. Accordingly, the following three conditions were included in the experiment:

- Paper Map (P-Map).
  This is a baseline condition that reflects the current situation in the Griffon where aircrew (i.e., the MC) navigate using a hand-held paper map and detect and identify targets without aid of a sensor.

- Moving Map (M-Map)

[1] An ERSTA system for the CH-146 fleet had not been acquired within the timeframe of this study. Therefore, the ERSTA system that was used in this study was intended only as an approximate representation. Although an attempt was made to provide the general functionality of the anticipated ERSTA system, the full ERSTA capabilities (especially of the sensor) were not represented. For this reason, the term "ERSTA-like system" is used in this document.

In this condition, the MC was provided with a digital moving map positioned on the MC lap. A paper map was also provided for use at the discretion of the MC. As in the paper map condition, the aircrew were required to detect and identify targets without aid of a sensor.

- Moving Map plus Sensor (M-Map/Sensor)
  In this condition, both the digital moving map (and the paper map) and the ERSTA-like sensor capability were provided. The ERSTA-like sensor (camera) image was displayed on the front centre console, i.e., where the current Griffon FLIR image is normally located. In this condition, aircrews were able to use the sensor image to support target detection and identification.

The TAMSS SA project is focused on situation awareness. We have argued, however, that assessing SA in isolation will not provide sufficient evidence to allow for good decisions in the modelling and simulation process. Accordingly, the present experiment was designed to sample all three dimensions of behaviour outlined in the CSE framework: task-relevant performance, workload, and situation awareness. Furthermore, the main thrust of the CSE framework is to provide converging measures, allowing researchers to give an overall perspective of performance that does not rely solely on a single construct or single method of measurement. To this end, both subjective and objective measures of task-relevant performance and situation awareness were obtained. For workload, only subjective measures were obtained.

1.2 Overview of measures

Task-relevant Performance - In this experiment, pilots flew realistic zone-recce missions (see descriptions in Annex A). For each mission a primary objective was defined and details were given concerning the flight path leading to the Release Point (RP). Pre-mission information was given concerning known position and movement of friendly and enemies forces in the area. Aircrew planned their post RP routes and observation points in a pre-mission session. To objectively assess the impact of the moving map capability on navigation, the positioning of the ownship relative to the defined flight ingress corridors leading to the RP was measured. The impact of the ERSTA-like sensor was objectively measured as the distance at which the aircrew detected and identified targets. Subjective ratings of performance and of task difficulty were collected after each mission. Subjective measures of navigation and mission performance were obtained through questionnaires (see Annex B).

It was hypothesized that the digital moving map and the ERSTA-like sensor would affect how much time the MC spent looking down and inside the cockpit. This was objectively assessed by recording the head positioning of the MC throughout the missions.

Workload - Workload was assessed subjectively using questionnaires based on a modified NASA TLX. Subjective ratings for global workload were obtained as were ratings for specific segments (e.g., ingress, recce-zone, egress) in the missions. Objective measures of workload were not directly obtained.

Situation Awareness - The objective index of situation awareness was the percentage of objects that aircrew missed during each mission. After each mission, pilots also rated their perceived awareness overall and for specific information.

1.3. Predictions

It was expected that relative to the P-Map condition, the presence of the moving map Iin the M-Map and M-Map/Sensor conditions would increase the SA of the MC, especially in terms of spatial and navigational SA. It was also anticipated that the ERSTA-like capabilities would generally enhance MC performance, lower the difficulty of completing tasks for the MC, and lower the MC's workload. The moving map was also predicted to increase the MC's confidence in re-creating the mission. The digital moving map and sensor capabilities were not expected to significantly affect FP ratings.

2 Method

2.1 Participants

Participants were four male pilots from the Canadian Forces ranging in age from 26 to 40 years (M = 32). Years in the Canadian Forces ranged between 9 and 14.5 years (M = 12.125). Years as pilots ranged between 2 and 13 years (M = 6.5). All four pilots where right handed. The following table summaries estimated time in hours for various types of flights.

Table 2.1 Estimated Flight Time

Type of Flight	**Estimated time (in hours)**
1. Total flight time	Range 750-2500 (M = 1612.5)
2. Total rotary wing	Range 500-2300 (M = 1400)
3. Total Griffon	Range 400-900 (M = 625)
4. Time spent using a flight simulator	Range 20-350 (M = 147.5)

All four participants had some experience with flight simulators. These included full motion CH-146 as well as CF-18, 212 simulators, Bell 212/412 and AH-64A Apache. One of the four participants had experienced with an ERSTA system prior to this experiment. This participant served as an ERSTA operator (10-15 hours) in a simulator environment. Two of the four participants were very familiar with the Gagetown NB area, and thus with the synthetic terrain environment that was used in the present experiment.

2.2 Design

This experiment compared the P-Map versus M-Map versus M-Map/Sensor conditions. The objective and subjective measures of the three core constructs in the CSE framework, situation awareness, workload, and task-relevant performance are shown in Table 1.1.

Table 2.2 CSE Measures

	Type of Measure	
CSE Domain	**Objective**	**Subjective**
Task-Relevant Performance	Navigation along defined flight corridors Distance from objective(s)/targets for detection & identification Head positioning of MC	Ratings of performance and task difficulty
Situation Awareness	Detection of airborne and ground objects	Ratings of SA (specific and global)
Workload	Not obtained	Ratings of workload

2.3 Materials and Measures

Questionnaires - The subjective measurements of situation awareness, workload, and performance were conducted at the end of each mission and at the end of the experiment. For each mission, separate questionnaires were completed by the FP and the MC. Participants rated variables on a number of scales (refer to Annex C). In addition, before starting the experiment, participants completed a background questionnaire (see Annex D), which included questions about the number of tactical, Griffon, and simulator flying hours they had logged.

Head Position of MC – Head position data was collected online (30 hz) to determine where the MC was looking throughout each mission. From this data, percent head-up versus head-down time could be calculated.

Development of Mission Scenarios – An important activity in this experiment was to develop representative and realistic tactical scenarios that could be used for both for this experiment and as a template for scenarios in the follow on experiment (Experiment 3) in the TAMSS SA program. This goal was accomplished through input from three subject-matter experts (SMEs) who were selected to provide different backgrounds and perspectives. One SME was provided by DND. This SME had no CH-146 Griffon experience but he was a highly experienced Kiowa pilot with experience in tactical helicopter operations. The second SME was a highly experienced Griffon pilot with tactical experience and with experience at DND LATEF facility in Gagetown NB. This SME had recently (< 10 months) retired from the Canadian Forces. The third SME was a retired but highly experienced fighter jet pilot. This SME has a vast amount of experience in tactical operations involving air support.

Numerous entities were added to the terrain database, creating scenarios that would allow the experimenters to take measures of Situation Awareness, Workload, and Task-relevant performance. The following is a description of the database used and the additions made to the external scene for the purposes of the experiment.

Terrain database - The landscape database was a Virtual Reality model of a 40 km (east to west) by 50 km (north to south) section of CFB Gagetown, NB, divided into twenty 10 km by 10 km squares, or “tiles”. Due to computer system (memory) constraints, only 6 to 8 tiles (i.e., the minimum required to cover the terrain relevant to a given mission) were displayed during any one mission. The database contained a number of fixed, pre-determined geographical features (river, hills, forest) and man-made elements (barracks, various military installations, roads, and the flight base). Various entities, both moving and stationary, were added to the terrain database to create a number of mission scenarios (see below) in order to assess pilots’ situation awareness during missions.

The objects that pilots were to report on for the purpose of assessing their SA were inserted and controlled using STAGE software. These included:

(a) formation of five M113 armored personnel carriers (mission scenario 1),
(b) one CH-146 Griffon helicopter flying in a circle pattern (scenario 1),
(c) formation of BMP-3 light infantry vehicles (scenario 1),
(d) formation of six M1025 light tactical vehicles (all scenarios),
(e) formation of eight M-109 artillery vehicles (scenarios 1 and 2),
(f) platoon of 6 infantry tents (all scenarios),
(g) formations of M2A3 Bradley Fighting Vehicles (scenarios 1,2 and 4),

(h) formation of six M1A2 battle tanks (scenario 2),
(i) damaged M939A2 5-ton truck (scenario 2),
(j) formation of four BTR-80 armoured personnel carriers (scenario 2),
(k) formation of six M110 artillery vehicles (scenario 3),
(l) crashed Mi-28 attack helicopter (scenario 3),
(m) formation of six M270 self-propelled rocket launchers (scenario 3),
(n) formations of HUM Avenger armoured vehicles (scenarios 1, 3 and 4),
(o) formation of five M1045 TOW missile carrier vehicles,
(p) downed Su-25 ground attack airplane, and
(q) formation of four ZSU-23-4 self-propelled anti-aircraft guns.

The vehicles were places so as to be on or near the trajectories or Restricted Operation Zones (ROZ's). Most entities or formations were stationary, but each scenario included at least two formations of moving vehicles (these tended to be vehicle formations that participants had not been briefed on at the outset of their missions). All entities were scaled to their normal size relative to the database.

*Mission Scenarios – F*our mission scenarios were developed, with terrain features and vehicles as described above. Descriptions of the scenarios are included in Annex A. The missions were roughly equivalent in complexity and number of entities, and all followed a general schema. Participants were first briefed on the general context of the mission, an operation that was designed to resemble United Nations peace support operations that have been put into action on various fronts throughout the Balkans and the Middle East in recent years.

Each mission consisted of a starting point (which also served as endpoint), a release point (RP) into the Restricted Operations Zone (ROZ), a point through which the ownship was supposed to exit the ROZ, and an intermediate waypoint connecting both the RP and the ROZ to the start/endpoint of the scenario. The start/end point, intermediate waypoint, RP and ROZ exit point were all connected by corridors within which the aircrew were to keep the ownship. The ownship's trajectory within the ROZ was left to the discretion of the pilots[2].

Each mission began with the ownship airborne at approximately 400 feet above ground level at the start point, and oriented towards the first waypoint. The waypoints were given to the pilots on a paper map and were displayed on the digital moving map, but the terrain database itself did not have any waypoint markers. Participants were instructed to reach the RP within approximately 15 minutes of having started the mission, and were given a maximum of 30 minutes to observe activity in the ROZ. They were instructed to maintain a maximum altitude of 500 feet while transiting from the start/end point and the ROZ, and a maximum of 250 feet in the ROZ (the ROZ was assumed to be capped by active high-speed airspace).

In each mission, participants were given the task of locating and assessing the state of an objective (generally a bridge or some other strategic landmark). They were also instructed to report on any entities, air or ground, they detected during the mission. Participants were informed in advance of the entities they were expected to encounter, but each mission included three entities (one enemy formation, one friendly formation, and one downed vehicle) that were not briefed. Also, each mission included unscripted weapons activity (directed either at the ownship or at entities in the terrain) that was controlled on-the-fly by an experimenter using the STAGE software. The unexpected vehicles and the unscripted weapons activity were included to test aircrew SA with respect to unexpected entities and events.

[2] The ROZ was the area within which the actual reconnaissance mission was supposed to take place. The participants were therefore given free reign to determine how they would explore it.

2.4 Procedure

Upon arrival at the CACR lab, participants were provided with information about the general purpose of the experiment and were given an overview of the two-day schedule. Participants then completed an informed consent and the personal (experience) background questionnaire. Following the information session, the participants flew a practice session before beginning the experimental sessions. For the practice session, each participant flew until they felt comfortable flying tactical with the simulator environment.

Participants were run in pairs, alternating between MC versus FP roles from one mission to the next. In total, each pair took part in six missions, with each participant serving as the MC for three missions and as the FP for three missions. Each participant served as the MC and as the FP in the Paper Map, Moving Map, and Moving Map + Sensor conditions.

Testing took place across two days. Four missions were flown day one: two missions for the Paper Map condition and two missions for the Moving Map condition. On the second day, two missions were flown for the Moving Map + Sensor condition.

Two experimenters assisted in this experiment. One experimenter monitored and controlled specific events in the scenarios using STAGE. The second experimenter was an experienced SME. This SME provided radio contact/communications and also served the role as the ERSTA-like operator in the Moving Map + Sensor condition. The SME communicated with the pilots via the simulator communications system. For the ERSTA role, the SME operated an ERSTA-like station that was situated behind the cockpit.

Each mission took approximately 20 minutes to complete. After each mission, the participants were asked to fill out the mission questionnaires. At the end of the second day the participants were asked to fill out a final questionnaire.

3 Results

The experimental goals were to extend the evaluation of the Cognitive System Engineering (CSE) framework proposed by the CACR for evaluating the impact of novel technology on aircrew in the CH146 Griffon helicopter. To do this, the impact of a prototyped ERSTA-like system was assessed with a particular focus on how the ERSTA-like system affects the performance, situation awareness and workload of the MC. Three conditions were examined: P-Map versus M-Map versus M-Map/Sensor.

Primary activities of the present experiment included a) integration of an emulation of the DND CH-146 ERSTA-like system into the CACR simulator using HLA protocol, (b) development of realistic scenarios for assessing performance, SA and workload in a tactical environment, (c) further development of the data collection capabilities of the CACR simulation facility and (d) further development of a questionnaire battery for assessing workload. As summarized previously in Table 1.2, objective and subjective measures were taken. Because of the small sample size (four participants), only descriptive statistics are reported and only one of the objective measures is briefly summarized.

3.1 Objective Measures

Task-Relevant Performance. Head position data for the MC was collected throughout each mission. However, technical difficulties are such that stable and complete data was only obtained for one participant. This data for this participant showed that percent head-up time was greater in the M-Map (49%) and M-Map/Sensor (48%) conditions than in the P-Map (33%) condition. This suggests that the ERSTA-like installation had the positive benefit of allowing the MC to spend more time looking outside the cockpit. Head-up time should impact on flight safety and enhance the contribution of the MC in detecting and responding to information external to the cockpit. The results suggest that the MC was better able to navigate along the flight corridors when the moving map was present as compared to the P-Map condition where only a hand map was available. In addition, it is clear that objectives and targets could be detected and identified at a greater distance when the ERSTA-like sensor capability was present.

Situation Awareness – Aircrew were generally proficient at detecting the relevant airborne and ground objects, regardless of which condition they were in. However, in order to achieve a high degree of realism, relative few objects were placed in the experimental scenarios. To obtain a more sensitive objective index of SA, future scenarios will need to include more objects, some of which would be expected and others that would be unexpected.

3.2 Post-Mission Subjective Ratings

After each mission, the MC and the FP each completed subjective questionnaires in which they rated their performance, difficulty of completing tasks, situation awareness and workload. The responses to these questionnaires are given separately for the FP versus the MC position.

Flying Pilot (FP). The subjective ratings for the FP position are summarized and shown in Annex E. On average, participants rated their *performance* in the FP position as generally better in the M-Map (4.5) and M-Map/Sensor (4.9) condition than in the P-Map (4.3) condition. These values all fall within the self-rated categories of Adequate to Good performance. Relative to the P-Map condition, the M-Map and M-Map/Sensor capabilities were judged as positively affecting most aspects of navigation and positioning of the aircraft.

Subjective ratings showed that regardless of condition, *difficulty of task completion* was usually rated as easy to moderate. However, many tasks were judged to be easier in the M-Map (2.7) and M-Map/Sensor (2.6) conditions than in the P-Map (3.35) condition. The perceived benefits of the ERSTA-like capabilities on task difficulty were especially evident for finding waypoints, controlling heading and altitude. As anticipated, there was no impact of the ERSTA-like system on tasks such as cross-checking instruments and controlling airspeed.

Ratings of *situation awareness* of aircraft systems were similar across the P-Map (4.57), M-Map (4.65) and M-Map/Sensor (4.9) conditions. These values refer to moderate to borderline high SA. Similarly, awareness of mission-relevant tactical information was generally undifferentiated for the FP role, although rated awareness did tend to increase across the P-Map (4.2), M-Map (4.4) and M-Map/Sensor (4.7) conditions. Average ratings of spatial/navigational awareness showed the same trend from P-Map (3.9), M-Map (4.2) and M-Map/Sensor (4.4) conditions. Ratings of awareness of crew activity were similar in the P-Map (4.75), M-Map (4.5) and M-Map/Sensor 4.63) conditions.

On average, ratings of FP workload did not differ across the P-Map (3.0), M-Map (2.95) and M-Map/Sensor (2.9) conditions. As expected, participants did note that FP workload was higher during enemy engagement and when hovering the simulator.

Mission Commander (MC). The subjective ratings for the MC position are summarized and shown in Annex F. After each mission the participant filling the MC role was required to *re-create (draw) the mission* using the paper from the mission map. They were required to indicate the order of waypoints/landmarks visited, showed the flight path with lines and identify the type and location of activity that took place during the mission. Following this, the participant rated their confidence in the *re-creation* of the mission. The average rated confidence tended to increase across the P-Map (4.13) to the M-Map (4.6) and M-Map/Sensor (4.75) conditions. Participants in the MC position noted that it was easy to identify terrain with the SA that was provided by the of the moving map display, but that some confusion may occur if there were any differences between the moving map and the paper map. It was also noted that it was difficult to re-create a mission on a paper map when the mission has been executed using a moving map.

Ratings of *performance* for various tasks in the MC position increased on average from “adequate” in the P-Map (4.4) condition to “good” in the M-Map (5.1) and M-Map/Sensor (5.0) conditions. As expected, performance ratings in the M-Map and M-Map/Sensor conditions were noticeably higher than the P-Map condition for the navigation tasks such as finding waypoints, reading the map and using the map to navigate. The ERSTA-like capabilities were also rated as enhancing the positioning of the aircraft in the recce zone.

For the MC position, average rated *difficulty* of performing tasks was greater in the P-Map (4.14) than in the M-Map (2.75) and M-Map/Sensor (2.6) conditions. These differences were especially evident for finding waypoints, reading and using the map information, route planning and positioning the aircraft in the recce zone. Similarly, the difficulty of getting information during a mission was on average higher P-Map (3.71) than the M-Map (2.8) and M-map/Sensor (2.45) conditions.

Ratings of *situation awareness* of tactical information relevant to the mission were generally high and undifferentiated across the P-Map (4.86) versus M-Map (4.56) conditions. Rated awareness tended to be higher in the M-Map/Sensor (5.31) condition. The SA ratings were noticeably higher in the M-Map/Sensor condition for tracking the unfolding of a mission and for anticipating future events. Rating of *spatial/navigational awareness* in the MC position also increased from the P-Map (3.93) to the M-Map (4.75) and M-Map/Sensor (5.75) conditions. Importantly, these ratings showed a clear advantage of the M-Map/Sensor condition for locating ownship relative to the objective (e.g., bridge) and relative to enemy activity as well as for awareness of the general layout of the navigated area. For awareness of *crew activities* while in the MC position, average ratings did not differ between the P-Map (4.5) and M-Map (4.63) conditions, but were generally high in the M-Map/Sensor (5.5) condition.

Ratings of *workload* during a mission did not differ dramatically across the three conditions, but on average there was a trend toward decreased subjective workload from the P-Map (3.95) to the M-Map (3.30 and M-Map/Sensor (3.1) conditions. As expected, ratings of workload were highest for activity in the recce zone as compared to the Ingress and Egress activities. Written comments from participants confirmed that workload for the MC was high in the recce zone “due to the number of agencies that needed to be contacted on different frequencies”. It was also noted that high workload for the MC in the recce zone was mainly associated with trying to maintain SA of ownship location. One piloted noted that the moving map reduces workload related to navigation thereby freeing more time for msn work (comms, search etc.).

3.3 Post-Mission Subjective Ratings

At the end of the second day of testing, participants completed a questionnaire to directly compare the three experimental conditions for both the FP and for the MC roles. The average ratings are shown in Annex G. For the FP position, these comparisons show that relative to the P-Map condition both the M-Map and the M-Map/Sensor conditions were perceived as improving most aspects of the FP’s SA, communications between the FP and the MC, and the FP’s performance. Similar enhancements were reported for the MC position.

4. Conclusions

The ability to generalize from this experiment is limited in that only four participants were run. However, the results are consistent in showing perceived advantages for the ERSTA-like digital moving map and sensor capabilities over the current Griffon map and sensor capabilities. Participants agreed that the moving map and sensor enhanced the MC's performance and SA while lowering task difficulty and workload. There was some indication of these benefits being transferred to the FP, particularly in terms of the aircrew's ability to position the aircraft and to maintain tactical flight. In addition, the head tracking data showed that relative to the P-Map condition, the MC was able to spend more time looking up and out of the cockpit in the M-Map and M-Map/Sensor conditions.

The results of this experiment provide a solid foundation for developing the third and final experiment in the TAMSS SA project. Of importance is that (a) the ERSTA-like system was effectively modeled and integrated into the simulator environment using HLA protocol, (b) the scenarios that were developed represented realistic tactical missions, (c) the questionnaire battery developed for obtaining subjective measures proved to be sensitive enough to index and differentiate performance, SA, task difficulty and workload across the three experimental conditions.

ANNEX A
Mission Scenarios

Tactical Scenario - Peace Support Operations

It is day 10 of Op NOMAD. Op NOMAD is the UN counteroffensive to push the final elements of the FDN troops out of the territory formerly known as Gagetownia. The FDN troops have been invading this territory for the past 14 months, conducting sporadic attacks on innocent civilians in an attempt to drive them out of the territory. Recently, in the past four months, the attacks have increased in number and in ferocity.

A number of emergency UN meetings have occurred resulting in a UN Chapter 6 operation (Op NOMAD) with the main objective to force the FDN troops out of the territory and allow the local Gagetownians to live in peace.

The FDN are a well equipped para-military organization who have been trained by Soviet forces, having been occupied as a soviet state for many years. Their equipment is predominantly Soviet based.

Future MNB operations require a number of critical areas to be maintained intact for the UN troops to continue the push to the St John River. These key areas are the bridges crossing the Oromocto, Nerepis and Otnabog Rivers and choke points out of the hilled areas on the West side of the St John river leading to the main river crossing areas used by the FDN for their initial invasion some 14 months ago.

The UN force is being led by the UN Multi-National Brigade (UNMNB) under the command of BGen Stolitchnoya (callsign Stiletto) from Lithuania. The main UN offensive has pushed the main FDN forces out of the territory. However, it is expected that a number of layback patrols have remained in the area to disrupt the UN operation and slow down the advance. This will allow time for the FDN forces to regroup and attempt to re-start their guerrilla activities.

Canada has provided the following forces:

- a Mech Inf Coy (A Coy 2PPCLI) attached to a UK Inf Bn
- a Recce Tp (A Tp LdSH) attached to a GE armoured unit
- a helicopter Flt (B Flt 408 Sqn) assigned to MNB HQ
- fighter assets from 4 Wing Cold Lake

Other UN assets of importance include:

- Arty (M109) and Armd (Leo 2) from the German 5 Spa-Panzer Div (SPD)
- UK Inf Bn (3 Bn Royal Grenadiers)
- US Inf Bn (2 Bn 1 ID)
- AWACs support
- CAS (GR8s) from RAF Wittering, deployed to an undisclosed 5 ATAF field location
- CAS / CAP support (CF18s) from 4 Wing, deployed to an undisclosed 5 ATAF DOB

Currently, the helicopter unit is located some 45 km West of the objective area, at the Brockway Airfield (FL 480485).

The MNB has secured (albeit loosely) a number key areas, important to the Op NOMAD advance. These include:

- bridges at:
    - GL 105558
    - GL 097533
    - <u>GL 091499</u>
    - GL 063467
    - GL 098450
- choke points at:

- GL 187647
- GL 205578
- GL 190468
- GL 211431

You are a Griffon crew assigned to conduct Recce tasks with the newly equipped ERSTA system. The Comd UNMNB has been impressed with the support provided to date since the ERSTA is the best long range rapidly deployable Recce system available in the Bde. The ERSTA equipped Griffons played a key roll in aiding the rapid advance of the MNB in the past 9 days.

It is 0830 and you have been informed that you are required to complete a mission of significant importance. The mission needs to be done quickly since the momentum of the MNB push through the territory may be halted as a result of possible FDN activity.

The HQ has lost contact with a patrol securing the bridge at GL 091499. The last report from the patrol indicated that they had been fired at sporadically from the surrounding hills to the East of their positions. It is extremely important that the HQ determine the status of the bridge and if the FDN are attempting to mine or destroy the bridge.

Pre Flt Brief to Crew from Ops
Situation:

General:

- as per intro

En:

- likely en activity in area of GL 091499 (objective) (last contact by patrol in area)
- contract report - sniper activity in area GL 1856 - 6 hrs ago
- intsum - bypassed en units (Platoon -) East of 20 Easting
- contact report - en patrol raided village in area of GL 0449 - 12 hrs ago, appeared to be headed East

Fr:

- Recce Tp located in area GL 0555 (6 x HUM TOW)
- Arty Bty located at FL 998504 (8 x M109-A6)
- Inf located at GL 059531 (camouflaged tents)
- Patrol on bridge at GL 082519 (3 x HUM AVENGER + 1 x M2A3 BRADLEY)
- attached for duration of mission - W Bty through G24
- CAS on call from MAGIC (10 min. notice required)

Wx:

- 5000 OVC, 4 NM vis, localized drizzle, temp 15°, dewpoint 10°, pressure 29.95”
- sunrise: 1200Z, sunset: 0300Z

Airspace:

- restrictions as per ACO

Mission:

Gain observation on the bridge at GL 091499 to determine if the bridge is intact and observe the bridge until T43B elements arrive.

Execution:

General Outline:

- In line with the mission, you have three objectives:

  1. gain observation onto the bridge
  2. determine if the bridge is intact
  3. maintain observation until T43B arrives

Groupings and Tasks:

- You will be the sole CH146 equipped with ERSTA on the mission

Fire Support:

- arty is available on call throughout the mission through G24
- CAS is available through MAGIC on 10 min notice

AD Assets:

- 1 x M2A3 BRADLEY is located at GL 141579 (5 km Radius down to 50’)

Co-ord Inst:

- timings: depart on mission NLT 0930
- route: as per ACO
- upon passing RP contact Bde HQ (C/S 92) and advise of ETA on observation area
- maintain contact with 92 through-out Recce phase

Service Support:

- DEWS is installed and configured as required
- FARP at GL 027481 (open 1000-1030) - fuel only (HEMTT Fuel Bowser)
- FSH located at FL 884566
- pers eqpt - SOP

Command and Signals:

Command:

- UC 408 Sqn B Flt
- TACCON Bde HQ (C/S 92)

Codewords:

- objective under observation SPYGLASS
- objective intact MANHOLE
- objective destroyed COLDSTART

COMMs:

- as per CEOIs

Airspace Control Orders

A special helicopter corridor has been reserved for this mission:

	Co-ord Point	Location	Altitude	Time (Z)
Ingress	TWEED	FL 560565	< 500'	0930 -1000
	BLISSVILLE	FL 912532		
	FINNEGANS	FL 995577		
RP	CLONES	GL 057552	< 250'	N/A
Egress	PETERSVILLE	GL 046498	< 500'	1000 -1100
	BLISSVILLE	FL 912532		
	TWEED	FL 560565		

The area in the vicinity of the objectives has been co-ordinated with MNB HQ to be restricted from other friendly helicopter activity except for emergency operations and enemy contact. The Restricted Operations Zone (ROZ) is capped at 250' and is bounded by:

- GL 106442
- GL 077450
- GL 095575
- GL 131563

There is an active LLTR immediately South of the objective bridge, passing immediately above the ROZ (250'-500'), one way, headed SW. It is expected that some friendly fighter activity may be using the LLTR on egress from BAI missions in FDN held territory East of the St John River. The LLTR is aligned with:

- GL 2756 and FL 9039

All aircraft activity in the territory is co-ordinated with AWAC (Magic). Upon passing any co-ord point or release point a call is to be made indicating your callsign and the point you passing.

PL FIR
FL 850550, FL 960613, GL 040633, FL 222655
PL OAK
FL 850440, GL 046498, GL 256575
PL ASH
FL 850330, GL 078371, GL 269496
PL CAT
FL 956690, FL 910623, FL 897580, FL 924465, FL 992405, FL 960330
PL DOG
FL 965686, FL 967640, GL 006553, GL 070435, GL 087412, GL 079369, GL 117338
PL HORSE
GL 000720, GL 037662, GL 059588, GL 124550, GL 114522, GL 172502, GL 247389

Communications Electronic Operating Instructions:

COMMs:

Unit	C/S	Freq	Crypto
AWAC	MAGIC	HQII / A19.225	No
Bde HQ	92	34.50	Fill 5
Patrol	I23A	33.90	Fill 4
Arty	G24	35.20	Fill 3
Recce Tp	T43B	42.65	Fill 1
Flt Ops	0	49.90	Fill 2
FARP	52C	46.50	Fill 2
CAS (on call)	KUGAR	HQII / A03.625	No

DEWS:

NOMAD Program 2

IFF:

IFF Mode	Time	Code
Mode 1:	0900-0930	02
	0930-1000	73
	1000-1030	61
	1030-1100	51
	1100-1130	40
	1130-1200	22
Mode 2:	N/A	1324
Mode 3:	1200	
Mode 4:	0000z-1200z	A
	1200z-2400z	B

Experimenter Inputs:

The sortie will commence with the Griffon safely airborne at the 2nd pre-planned Co-ordination Point, at an altitude of 400 feet AGL, on track and heading to the next Co-ordination Point. Once the aircrew is comfortable the simulation will be uncaged; the time will be 0945Z.

Experimenter Inputs (not for expert user consumption):

These activities are **NOT** briefed to the crew – in order to allow the aircrew to interact with the dynamic of the synthetic environment and react accordingly.

The following dynamic events will be programmed to occur during the "sortie":

- 5 x M113 APCs will transit NW on the black track from GL 050553 to GL 023569. The APCs need to be moving as the helicopter is transiting between FINNEGAN and CLONES.
- A burning/crashed AH-64 Apache will be on the ground at GL 070554.
- 4 x BMP Armoured Fighting Vehicles will transit North on the road from GL 092470 to GL 114522. The BMPs need to be moving as the Griffon reaches CLONES.

Tactical Scenario - Peace Support Operations

It is day 10 of Op NOMAD. Op NOMAD is the UN counteroffensive to push the final elements of the FDN troops out of the territory formerly known as Gagetownia. The FDN troops have been invading this territory for the past 12 months, conducting sporadic attacks on innocent civilians in an attempt to drive them out of the territory. Recently, in the past three months, the attacks have increased in number and in ferocity.

A number of emergency UN meetings have occurred resulting in a UN Chapter 6 operation (Op NOMAD) with the main objective to force the FDN troops out of the territory and allow the local Gagetownians to live in peace.

The FDN are a well equipped para-military organization who have been trained by Soviet forces, having been occupied as a soviet state for many years. Their equipment is predominantly Soviet based.

Future MNB operations require a number of critical areas to be maintained intact for the UN troops to continue the push to the South and West of the St John River. These key areas are the bridges crossing the Nerepis River and choke points along the road paralleling the NW-SE rail line and extending South to the St. John River. Wellsford was a main crossing area used by the FDN during their initial incursion some 12 months ago.

The UN force is being led by the UN Multi-National Brigade (UNMNB) under the command of BGen Ruberg (callsign Thunder) from Lithuania. The main UN offensive has pushed the main FDN forces out of the territory. However, it is expected that a number of layback patrols have remained in the area to disrupt the UN operation and slow down the advance. This will allow time for the FDN forces to regroup and attempt to re-start their guerrilla activities.

Canada has provided the following forces:

- a Mech Inf Coy (A Coy 2PPCLI) attached to a UK Inf Bn
- a Recce Tp (A Tp LdSH) attached to a US armoured unit
- a helicopter Flt (B Flt 408 Sqn) assigned to MNB HQ
- fighter assets from 4 Wing Cold Lake

Other UN assets of importance include:

- Arty (M109) and Armd (ABRAMS) from the 1st US Armd Div
- UK Inf Bn (3 Bn Royal Grenadiers)
- US Inf Bn (2 Bn 1 ID)
- AWAC support
- CAS (GR8s) from RAF Wittering, deployed to an undisclosed 5 ATAF field location
- CAS / CAP support (CF18s) from 4 Wing, deployed to an undisclosed 5 ATAF DOB

Currently, the helicopter unit is located some 40 km North of the objective area, at the Hersey Corner Airstrip (GL 100792).

The MNB has secured (albeit loosely) a number key areas, important to the Op NOMAD advance. These include:

- bridges at:
    - GL 091499
    - GL 093466
    - GL 099450
    - GL 088433
    - GL 089415
- choke points at:
    - GL 079370

- GL 017395
- FL 993403
- GL 226436

It is 0830 and you have been informed that you are required to complete a mission of significant importance. The mission needs to be done quickly since the momentum of the MNB push through the territory may be halted as a result of possible FDN activity.

The HQ has lost contact with a patrol securing the choke point at GL 079370. The last report from the patrol indicated that they had observed increased vehicular traffic and massing of Armd unit(s) to the South of their objective. It is extremely important that the HQ determine the status of the choke point and if the FDN are attempting to advance North.

Pre Flt Brief to Crew from Ops
Situation:

General:

- as per intro

En:

- en activity in area of GL 079370 (objective) (last contact by patrol in area)
- contract report - sniper activity in area GL 193431 - 3 hrs ago
- contact report - en patrol raided village in area of GL 2243 - 8 hrs ago, appeared to be headed West

Fr:

- Recce Tp located in area GL 0345 (6 x HUM TOW)
- Arty Bty located at FL 050503 (8 x M109-A6)
- Inf Platoon located at GL 107440 (camouflaged tents)
- Patrol on bridge at GL 088433 (4 x M2A3 BRADLEY)
- attached for duration of mission - W Bty through G24
- CAS on call from MAGIC (10 min. notice required)

Wx:

- 5000 OVC, 4 NM vis, localized drizzle, temp 15°, dewpoint 10°, pressure 29.95”
- sunrise: 1200Z, sunset: 0300Z

Airspace:

- restrictions as per ACO

Mission:

Gain observation on the choke point at GL 079370 (objective) to determine en activity and continue to observe until T43B elements arrive.

Execution:

General Outline:

- In line with the mission, you have three objectives:

4. gain observation onto the choke point
5. determine if there is any en advance to / beyond the choke point
6. maintain observation until T43B arrives

Groupings and Tasks:

- You will be the sole CH146 equipped with ERSTA on the mission

Fire Support:

- arty is available on call throughout the mission through G24
- CAS is available through MAGIC on 10 min notice

AD Assets:

- 1 x M2A3 BRADLEY is located at FL 954438 (5 km Radius down to 50')

Co-ord Inst:

- timings: depart on mission NLT 0930
- route: as per ACO
- upon passing RP contact Bde HQ (C/S 92) and advise of ETA on observation area
- maintain contact with 92 through-out Recce phase

Service Support:

- DEWS is installed and configured as required
- FARP at GL 141461(open 1000-1030) - fuel only (HEMTT Fuel Bowser)
- FSH located at GL 098630
- pers eqpt - SOP

Command and Signals:

Command:

- UC 408 Sqn B Flt
- TACCON Bde HQ (C/S 92)

Codewords:

- objective under observation TELEPHOTO
- objective secure from en LOCKDOWN
- en movement North of objective GALLOP

COMMs:

- as per CEOIs

Airspace Control Orders

A special helicopter corridor has been reserved for this mission:

	Co-ord Point	Location	Altitude	Time (Z)
Ingress	ROCKWELL STREAM BRIDGE	GL 013734	< 500’	0930 -1000
	KNOWLTON HILL	GL 060587		
	BIG BOG	FL 997517		
RP	RODDYS LAKE	GL 043443	< 250’	N/A
Egress	LYON BRIDGE ROAD	GL 096451	< 500’	1000 -1100
	KNOWLTON HILL	GL 060587		
	ROCKWELL STREAM BRIDGE	GL 013734		

The area in the vicinity of the objectives has been co-ordinated with MNB HQ to be restricted from other friendly helicopter activity except for emergency operations and enemy contact. The Restricted Operations Zone (ROZ) is capped at 250’ and is bounded by:

- GL 074333
- FL 985393
- FL 976430
- GL 135366

There is an active LLTR immediately West of the objective choke point, passing immediately above the ROZ (250’-500’), one way, headed NNE. It is expected that some friendly fighter activity may be using the LLTR on egress from BAI missions in FDN held territory SW of the St John River. The LLTR is aligned with:

- FL 9926 and FL 209778

All aircraft activity in the territory is co-ordinated with AWAC (Magic). Upon passing any co-ord point or release point a call is to be made indicating your callsign and the point you passing.

PL TROUT
FL 890720, FL 964686, GL 107728, GL 210779
PL PERCH
FL 909501, GL 060587, GL 173569, GL 253590
PL BASS
FL 900320, GL 017395, GL 096451, GL 260486
PL LION
FL 931738, FL 898560, GL 010310
PL TIGER
GL 237383, GL 167607, GL 138797

Communications Electronic Operating Instructions:

COMMs:

Unit	C/S	Freq	Crypto
AWAC	MAGIC	HQII / A89.625	No
Bde HQ	92	46.25	Fill 5
Patrol	I22A	39.80	Fill 4
Arty	G14	34.50	Fill 3
Recce Tp	T13B	48.65	Fill 2
Flt Ops	0	49.90	Fill 1
FARP	52D	46.50	Fill 1
CAS (on call)	HAWK	HQII / A67.125	No

DEWS:

NOMAD Program 1

IFF:

IFF Mode	Time	Code
Mode 1:	0900-0930	73
	0930-1000	61
	1000-1030	53
	1030-1100	41
	1100-1130	10
	1130-1200	70
Mode 2:	N/A	1324
Mode 3:	1200	
Mode 4:	0000z-1200z	A
	1200z-2400z	B

Experimenter Inputs:

The sortie will commence with the Griffon safely airborne at the 2nd pre-planned Co-ordination Point, at an altitude of 400 feet AGL, on track and heading to the next Co-ordination Point. Once the aircrew is comfortable the simulation will be uncaged; the time will be 0945Z.

Experimenter Inputs (not for expert user consumption):

These activities are **NOT** briefed to the crew – in order to allow the aircrew to interact with the dynamic of the synthetic environment and react accordingly.

The following dynamic events will be programmed to occur during the "sortie":

- 6 x M1A2 Abrams MBTs will transit WSW on the road from GL 040497 to FL 991481. The Abrams need to be moving as the helicopter is transiting to, but short of BIG BOG.
- A burning M939A2 5-Ton Truck will be on the ground at GL 067451.
- 6 x BTR 80s will transit North on the road from GL 100336 to GL 079368. The BTRs need to be moving as the Griffon reaches RODDYS LAKE.

Tactical Scenario - Peace Support Operations

It is day 10 of Op NOMAD. Op NOMAD is the UN counteroffensive to push the final elements of the FDN troops out of the territory formerly known as Gagetownia. The FDN troops have been invading this territory for the past 10 months, conducting sporadic attacks on innocent civilians in an attempt to drive them out of the territory. Recently, in the past two months, the attacks have increased in number and in ferocity.

A number of emergency UN meetings have occurred resulting in a UN Chapter 6 operation (Op NOMAD) with the main objective to force the FDN troops out of the territory and allow the local Gagetownians to live in peace.

The FDN are a well equipped para-military organization who have been trained by Soviet forces, having been occupied as a soviet state for many years. Their equipment is predominantly Soviet based.

Future MNB operations require a number of critical areas to be maintained intact for the UN troops to continue the push to the North and West of the St John River. These key areas are the bridges West of Otnabog Lake and choke points on the West side of the St John river, used by the FDN for their initial incursion some 10 months ago.

The UN force is being led by the UN Multi-National Brigade (UNMNB) under the command of BGen Stanlowski (callsign Grimace) from Poland. The main UN offensive has pushed the main FDN forces out of the territory. However, it is expected that a number of layback patrols have remained in the area to disrupt the UN operation and slow down the advance. This will allow time for the FDN forces to regroup and attempt to re-start their guerrilla activities.

Canada has provided the following forces:

- a Mech Inf Coy (A Coy 2PPCLI) attached to a UK Inf Bn
- a Recce Tp (A Tp LdSH) attached to a GE armoured unit
- a helicopter Flt (B Flt 408 Sqn) assigned to MNB HQ
- fighter assets from 4 Wing Cold Lake

Other UN assets of importance include:

- Arty (MLRS) and Armd (Leo 2) from the German 5 Spa-Panzer Div (SPD)
- UK Arty Bn (21st FA)
- US Inf Bn (2 Bn 1 ID)
- AWAC support
- CAS (GR8s) from RAF Wittering, deployed to an undisclosed 5 ATAF field location
- CAS / CAP support (F18s) from 4 Wing, deployed to an undisclosed 5 ATAF DOB

Currently, the helicopter unit is located some 35 km South West of Black Clarendon (FL 8521).

The MNB has secured (albeit loosely) a number key areas, important to the Op NOMAD advance. These include:

- bridges at:
    - GL 170651
    - GL 187647
    - GL 196652
    - GL 207649
- choke points at:
    - GL 204704
    - GL 174710
    - GL 139640

- GL 085735
- GL 041633
- GL 197657

You are a Griffon crew assigned to conduct Recce tasks with the newly equipped ERSTA system. The Comd UNMNB has been impressed with the support provided to date since the ERSTA is the best long range rapidly deployable Recce system available in the Bde. The ERSTA equipped Griffons played a key roll in aiding the rapid advance of the MNB in the past 7 days.

It is 0830 and you have been informed that you are required to complete a mission of significant importance. The mission needs to be done quickly since the momentum of the MNB push through the territory may be halted as a result of possible FDN activity.

The HQ has lost contact with a patrol securing the bridges leading to the choke point / objective area at GL 197657. The last report from the patrol indicated that they had taken mortar fire at sporadically from the North and West of their positions. It is extremely important that the HQ determine the status of the bridges and the choke point, and if the FDN are attempting to mine or destroy the bridges and /or advance South through the choke point.

Pre Flt Brief to Crew from Ops
Situation:

General:
- as per intro

En:
- likely en activity in area of GL 197657 (objective) (last contact by patrol in area)
- contract report - sniper activity in area GL 1774 - 8 hrs ago
- intsum – ZSU-234 activity at Tantawanta Bridge - 4 hrs ago
- contact report - en patrol raided village in area of Fentons - 6 hrs ago, appeared to be headed North West

Fr:
- Recce Tp located in area GL 1472 (6 x HUM TOW)
- MLRS Bty located at GL 135585 (6 x M270 MLRS)
- Inf located at GL 210610 (camouflaged tents)
- Patrol at road intersection GL 178629 (4 x HUM AVENGER)
- attached for duration of mission - W Bty through G24
- CAS on call from MAGIC (10 min. notice required)

Wx:
- 5000 OVC, 4 NM vis, localized drizzle, temp 15°, dewpoint 10°, pressure 29.95”
- sunrise: 1200Z, sunset: 0300Z

Airspace:
- restrictions as per ACO

Mission:

Gain observation on the key bridges, determine if intact and observe the choke point at GL 197657 until T43B elements arrive.

Execution:

General Outline:

- In line with the mission, you have three objectives:

7. gain observation onto the key bridges
8. determine if the bridges are intact
9. maintain observation on the choke point until T43B arrives

Groupings and Tasks:

- You will be the sole CH146 equipped with ERSTA on the mission

Fire Support:

- MLRS is available on call throughout the mission through G24
- CAS is available through MAGIC on 10 min notice

AD Assets:

- 1 x M2A3 BRADLEY is located at GL 249634(5 km Radius down to 50')

Co-ord Inst:

- timings: depart on mission NLT 0930
- route: as per ACO
- upon passing RP contact Bde HQ (C/S 92) and advise of ETA on observation area
- maintain contact with 92 through-out Recce phase

Service Support:

- DEWS is installed and configured as required
- FARP at GL 068548 (open 1000-1030) - fuel only (HEMTT Fuel Bowser)
- FSH located at GL 023485
- pers eqpt - SOP

Command and Signals:

Command:

- UC 408 Sqn B Flt
- TACCON Bde HQ (C/S 92)

Codewords:

- objective under observation WINDSCREEN
- all bridges intact FANCY
- any bridge destroyed BITTER
- en movement South of choke point LOCOMOTIVE

COMMs:

- as per CEOIs

Airspace Control Orders

A special helicopter corridor has been reserved for this mission:

	Co-ord Point	Location	Altitude	Time (Z)
Ingress	BLACK CLAREDON	FL 902340	< 500'	0930 -1000
	WELLSFORD	GL 078370		
	BELL BRIDGE RUIN	GL 097496		
RP	DAY HILL	GL 193545	< 250'	N/A
Egress	MALLORY-KERR ROADS	GL 106578	< 500'	1000 -1100
	WELLSFORD	GL 078370		
	BLACK CLAREDON	FL 902340		

The area in the vicinity of the objectives has been co-ordinated with MNB HQ to be restricted from other friendly helicopter activity except for emergency operations and enemy contact. The Restricted Operations Zone (ROZ) is capped at 250' and is bounded by:

- GL 120627
- GL 114683
- GL 232684
- GL 212622

There is an active LLTR immediately West of the objective bridge, passing immediately above the ROZ (250'-500'), one way, headed SSE. It is expected that some friendly fighter activity may be using the LLTR on egress from BAI missions in FDN held territory North of the St John River. The LLTR is aligned with:

- GL 127820 and GL 200320

All aircraft activity in the territory is co-ordinated with AWAC (Magic). Upon passing any co-ord point or release point a call is to be made indicating your callsign and the point you passing.

PL RAM
FL 891789, FL 992740, GL 150734, FL 262669
PL STEER
FL 903627, GL 023570, GL 193502, GL 262477
PL HOG
FL 898419, FL 947442, GL 078370, GL 230337
PL ROD
FL 992740, GL 041633, GL 048500, GL 000333
PL REEL
GL 243792, GL 262669, GL 262447, GL 230337

Communications Electronic Operating Instructions:

COMMs:

Unit	C/S	Freq	Crypto
AWAC	MAGIC	HQII / A73.925	No
Bde HQ	92	36.25	Fill 5
Patrol	I22A	59.80	Fill 3
Arty	G14	33.90	Fill 4
Recce Tp	T13B	42.65	Fill 1
Flt Ops	0	49.90	Fill 2
FARP	52D	46.50	Fill 2
CAS (on call)	TIGER	HQII / A48.625	No

DEWS:

NOMAD Program 1

IFF:

IFF Mode	Time	Code
Mode 1:	0900-0930	03
	0930-1000	51
	1000-1030	73
	1030-1100	41
	1100-1130	30
	1130-1200	00
Mode 2:	N/A	1324
Mode 3:	1200	
Mode 4:	0000z-1200z	A
	1200z-2400z	B

Experimenter Inputs:

The sortie will commence with the Griffon safely airborne at the 2nd pre-planned Co-ordination Point, at an altitude of 400 feet AGL, on track and heading to the next Co-ordination Point. Once the aircrew is comfortable the simulation will be uncaged; the time will be 0945Z.

Experimenter Inputs (not for expert user consumption):

These activities are **NOT** briefed to the crew – in order to allow the aircrew to interact with the dynamic of the synthetic environment and react accordingly.

The following dynamic events will be programmed to occur during the "sortie":

- 6 x M110 SP Howitzers will transit NNE on the road from GL 154508 to GL 169537. The M110s need to be moving as the helicopter is transiting between BELL BRIDGE RUIN and DAY HILL.

- A landed MI-28 Havoc will be on the ground at GL 209629.

- 4 x T-72 MBTs will transit South on the road from GL 203703 to the choke point / objective at GL 197657. The MBTs need to be moving as the Griffon reaches DAY HILL.

Tactical Scenario - Peace Support Operations

It is day 10 of Op NOMAD. Op NOMAD is the UN counteroffensive to push the final elements of the FDN troops out of the territory formerly known as Gagetownia. The FDN troops have been invading this territory for the past 8 months, conducting sporadic attacks on innocent civilians in an attempt to drive them out of the territory. Recently, in the past month, the attacks have increased in number and in ferocity.

A number of emergency UN meetings have occurred resulting in a UN Chapter 6 operation (Op NOMAD) with the main objective to force the FDN troops out of the territory and allow the local Gagetownians to live in peace.

The FDN are a well equipped para-military organization who have been trained by Soviet forces, having been occupied as a soviet state for many years. Their equipment is predominantly Soviet based.

Future MNB operations require a number of critical areas to be maintained intact for the UN troops to continue the push West and North of the St John River. These key areas are the bridges and access routes crossing the Oromocto and St. John (West of Gagetown) Rivers leading to the main incursion points used by the FDN for their initial invasion some 8 months ago.

The UN force is being led by the UN Multi-National Brigade (UNMNB) under the command of BGen Leboeuf (callsign Roaster) from France. The main UN offensive has pushed the main FDN forces out of the territory. However, it is expected that a number of layback patrols have remained in the area to disrupt the UN operation and slow down the advance. This will allow time for the FDN forces to regroup and attempt to re-start their guerrilla activities.

Canada has provided the following forces:

- a Mech Inf Coy (A Coy 2PPCLI) attached to a UK Inf Bn
- a Recce Tp (A Tp LdSH) attached to a GE armoured unit
- a helicopter Flt (B Flt 408 Sqn) assigned to MNB HQ
- fighter assets from 4 Wing Cold Lake

Other UN assets of importance include:

- Arty (M109) and Armd (Leo 2) from the German 5 Spa-Panzer Div (SPD)
- UK Arty Bn (21st FA)
- US Inf Bn (2 Bn 1 ID)
- AWAC support
- CAS (GR8s) from RAF Wittering, deployed to an undisclosed 5 ATAF field location
- CAS / CAP support (F18s) from 4 Wing, deployed to an undisclosed 5 ATAF DOB

Currently, the helicopter unit is located some 40 km South East of the objective area, at the Blue Mountain Correctional Facility (GL 223453).

The MNB has secured (albeit loosely) a number key areas, important to the Op NOMAD advance. These include:

- bridges at:
    - FL 904710
    - FL 926797
    - FL 929804
    - FL 978822
    - <u>FL 960725</u>
    - FL 970777
    - FL 996724
- choke points at:

- FL 988780
- FL 978775
- FL 963752
- FL 996717

You are a Griffon crew assigned to conduct Recce tasks with the newly equipped ERSTA system. The Comd UNMNB has been impressed with the support provided to date since the ERSTA is the best long range rapidly deployable Recce system available in the Bde. The ERSTA equipped Griffons played a key roll in aiding the rapid advance of the MNB in the past 6 days.

It is 0830 and you have been informed that you are required to complete a mission of significant importance. The mission needs to be done quickly since the momentum of the MNB push through the territory may be halted as a result of possible FDN activity.

The HQ has lost contact with a patrol securing the bridge at FL 960725. The last report from the patrol indicated that they had been fired at sporadically from the buildings to the South West of their positions. It is extremely important that the HQ determine the status of the bridge and if the FDN are attempting to mine or destroy the bridge.

Pre Flt Brief to Crew from Ops
Situation:

General:

- as per intro

En:

- likely en activity in area of FL 960725 (objective) (last contact by patrol in area)
- contract report - sniper activity in area FL 8980 - 4 hrs ago
- intsum – 2S6 activity in the area of Wood Meadow - 6 hrs ago
- contact report - en patrol raided village in area of Lower Lincoln - 6 hrs ago, appeared to be headed North West

Fr:

- Recce Tp located in area FL 9866 (6 x HUM TOW)
- MLRS Bty located at FL 982652 (6 x M270 MLRS)
- Inf located at FL 994770 (camouflaged tents)
- Patrol on bridge at FL 996724 (1 x M2A3 BRADLEY + 3 x HUM AVENGER)
- attached for duration of mission - W Bty through G24
- CAS on call from MAGIC (10 min. notice required)

Wx:

- 5000 OVC, 4 NM vis, localized drizzle, temp 15°, dewpoint 10°, pressure 29.95”
- sunrise: 1200Z, sunset: 0300Z

Airspace:

- restrictions as per ACO

Mission:

Gain observation on the bridge at FL 960725 to determine if the bridge is intact and observe the bridge until T43B elements arrive.

Execution:

General Outline:

- In line with the mission, you have three objectives:

10. gain observation onto the bridge
11. determine if the bridge is intact
12. maintain observation until T43B arrives

Groupings and Tasks:

- You will be the sole CH146 equipped with ERSTA on the mission

Fire Support:

- arty is available on call throughout the mission through G24
- CAS is available through MAGIC on 10 min notice

AD Assets:

- 1 x M2A3 BRADLEY is located at FL 960650 (5 km Radius down to 50’)

Co-ord Inst:

- timings: depart on mission NLT 0930
- route: as per ACO
- upon passing RP contact Bde HQ (C/S 92) and advise of ETA on observation area
- maintain contact with 92 through-out Recce phase

Service Support:

- DEWS is installed and configured as required
- FARP at GL 098722 (open 1000-1030) - fuel only (HEMTT Fuel Bowser)
- FSH located at FL 195545
- pers eqpt - SOP

Command and Signals:

Command:

- UC 408 Sqn B Flt
- TACCON Bde HQ (C/S 92)

Codewords:

- objective under observation ZOOM
- objective intact HARVEST
- objective destroyed RECOIL

COMMs:

- as per CEOIs

Airspace Control Orders

A special helicopter corridor has been reserved for this mission:

	Co-ord Point	Location	Altitude	Time (Z)
Ingress	CENTRAL HAMPSTEAD	GL 250590	< 500’	0930 -1000
	LAWFIELD-BOUNDARY ROADS	GL 139640		
	NW KNOWLTON HILL	GL 048609		
RP	BROAD ROAD CLEARING	FL 984636	< 250’	N/A
Egress	LAUVINA ROAD CLEARING	GL 006703	< 500’	1000 -1100
	LAWFIELD-BOUNDARY ROADS	GL 139640		
	CENTRAL HAMPSTEAD	GL 250590		

The area in the vicinity of the objectives has been co-ordinated with MNB HQ to be restricted from other friendly helicopter activity except for emergency operations and enemy contact. The Restricted Operations Zone (ROZ) is capped at 250’ and is bounded by:

- FL 920678
- FL 936792
- FL 975782
- FL 973700
- FL 945672

There is an active one way LLTR South of the objective bridge, headed ENE and passing immediately South of the ROZ (SFC to < 500’. It is expected that some friendly fighter activity may be using the LLTR on egress from BAI missions in FDN held territory West of the objective. The LLTR is aligned with:

- FL 8564 and GL 2575

All aircraft activity in the territory is co-ordinated with AWAC (Magic). Upon passing any co-ord point or release point a call is to be made indicating your callsign and the point you passing.

PL SLEET
FL 920832, GL 094835, GL 195794, GL 262669
PL HAIL
FL 901620, GL 171502, GL 249369
PL WAVE
FL 960410, FL 908510, FL 897561, FL 920832
PL RIPPLE
GL 070305, GL 097496, GL 141579, GL 139640, GL 243793

Communications Electronic Operating Instructions:

COMMs:

Unit	C/S	Freq	Crypto
AWAC	MAGIC	HQII / A11.125	No
Bde HQ	92	37.85	Fill 5
Patrol	I12A	58.50	Fill 1
Arty	G34	34.50	Fill 3
Recce Tp	T21B	30.65	Fill 2
Flt Ops	0	49.90	Fill 4
FARP	52S	46.50	Fill 4
CAS (on call)	STING	HQII / A55.525	No

DEWS:

NOMAD Program 4

IFF:

IFF Mode	Time	Code
Mode 1:	0900-0930	13
	0930-1000	41
	1000-1030	23
	1030-1100	61
	1100-1130	70
	1130-1200	21
Mode 2:	N/A	1721
Mode 3:	1200	
Mode 4:	0000z-1200z	A
	1200z-2400z	B

Experimenter Inputs:

The sortie will commence with the Griffon safely airborne at the 2nd pre-planned Co-ordination Point, at an altitude of 400 feet AGL, on track and heading to the next Co-ordination Point. Once the aircrew is comfortable the simulation will be uncaged; the time will be 0945Z.

Experimenter Inputs (not for expert user consumption):

These activities are **NOT** briefed to the crew – in order to allow the aircrew to interact with the dynamic of the synthetic environment and react accordingly.

The following dynamic events will be programmed to occur during the "sortie":

- 5 x M1045 HHMWV TOWs will transit NW on the black track from FL 983614 to FL 968640. The TOWs need to be moving as the helicopter is transiting NW KNOWLTON HILL.
- A burning/crashed SU-25 Frogfoot will be on the ground at FL 930697.
- 4 x ZSU-234s will transit South on the road from FL 965765 to FL 963746. The ZSU-234s need to be moving as the Griffon reaches BROAD ROAD CLEARING.

ANNEX B

Mission Assessment Questionnaires

TAMSS Experiment 2
Mission Assessment

Participant ID	
Date	
Time	
Mission number	
Scenario Code	
Condition	Hand Map Or Moving Map OR Moving Map + Sensor
Role	Mission Commander Or Flying Pilot

Instructions

If you have additional comments about any question or item, please write these on the back of the corresponding page.

M1. Rate how well you performed of each of the following tasks during this mission. Circle N/A if the item was not applicable to this mission.

	PERFORMANCE							
Task	very poor			adequate			very good	
Finding waypoints	1	2	3	4	5	6	7	NA
Control heading	1	2	3	4	5	6	7	NA
Control altitude	1	2	3	4	5	6	7	NA
Control airspeed	1	2	3	4	5	6	7	NA
Cross checking relevant instruments/symbology	1	2	3	4	5	6	7	NA
Using information from the external scene to control the aircraft	1	2	3	4	5	6	7	NA
Positioning the aircraft in recce area	1	2	3	4	5	6	7	NA
Maintaining tactical flight	1	2	3	4	5	6	7	NA

M2. Rate the difficulty of each of the following tasks during the mission. Circle N/A if the item was not applicable to this mission.

	DIFFICULTY							
Task	very easy			moderate			very difficult	
Finding waypoints	1	2	3	4	5	6	7	NA
Control heading	1	2	3	4	5	6	7	NA
Control altitude	1	2	3	4	5	6	7	NA
Control airspeed	1	2	3	4	5	6	7	NA
Cross checking relevant instruments/symbology	1	2	3	4	5	6	7	NA
Using information from the external scene to control the aircraft	1	2	3	4	5	6	7	NA
Positioning the aircraft in recce area	1	2	3	4	5	6	7	NA
Maintaining tactical flight	1	2	3	4	5	6	7	NA

M3. Rate your awareness of the status of the aircraft systems as it applies to your mission/task.

	AWARENESS							
	very low			moderate			very high	
Aircraft Systems overall	1	2	3	4	5	6	7	NA
Heading	1	2	3	4	5	6	7	NA
RAD Alt	1	2	3	4	5	6	7	NA
Airspeed	1	2	3	4	5	6	7	NA
Attitude	1	2	3	4	5	6	7	NA
	1	2	3	4	5	6	7	NA

M4. Rate your awareness of tactical information relevant to your mission (i.e. where do you need to go and what needs to be completed, mission goals and how is the mission unfolding).

	AWARENESS							
	very low			moderate			very high	
Overview of mission	1	2	3	4	5	6	7	NA
Unfolding of mission/keeping track of how mission unfolds	1	2	3	4	5	6	7	NA
Potential developments (anticipating future scenarios)	1	2	3	4	5	6	7	NA

Global mission goals	1	2	3	4	5	6	7	NA
Specific mission goals	1	2	3	4	5	6	7	NA
Enemy activities	1	2	3	4	5	6	7	NA
Friendly activities	1	2	3	4	5	6	7	NA
General threat	1	2	3	4	5	6	7	NA
Where I need to go	1	2	3	4	5	6	7	NA

M5. Rate your spatial/navigational awareness (i.e. where you need to go and location of ownship in relation to enemies, friendly units, target and other relevant objects and landmarks in the environment).

	AWARENESS							
	very low			moderate			very high	
Overall Spatial Orientation	1	2	3	4	5	6	7	NA
Ownship location in relation to target (e.g. bridge)	1	2	3	4	5	6	7	NA
Ownship location in relation to enemy activity	1	2	3	4	5	6	7	NA
Ownship location in relation to friendly activity	1	2	3	4	5	6	7	NA
Target location relative to enemy and friendly units	1	2	3	4	5	6	7	NA
Important landmarks	1	2	3	4	5	6	7	NA
General layout of the navigated area	1	2	3	4	5	6	7	NA

M6. Rate the following crew activity.

	very low			moderate			very high	
Overall quality of communication	1	2	3	4	5	6	7	NA
The usefulness of information provided by Mission Commander	1	2	3	4	5	6	7	NA

M7. Rate your workload during this mission. Circle NA if not applicable during this mission.

	WORKLOAD							
	very low			moderate			very high	
Ingress to first waypoint	1	2	3	4	5	6	7	NA
First waypoint to release point (RP)	1	2	3	4	5	6	7	NA
Recce zone [release point to target]	1	2	3	4	5	6	7	NA
Egress [target to end]	1	2	3	4	5	6	7	NA
Overall	1	2	3	4	5	6	7	NA

At any point, did you find that your workload was very different (e.g., much higher or lower) than across the mission as a whole? YES or NO

If yes, please elaborate:

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TLX WORKLOAD ASSESSMENT

Instructions. Place an X on each scale at the point that represents the magnitude of each factor in the mission you just performed. Refer to the Workload Scale Descriptions for definitions of each factor.

SEGMENT OF MISSION: **Ingress to first waypoint**

Mental demand LOW |----|----|----|----|----|----|----|----|----|----| HIGH

Physical demand LOW |----|----|----|----|----|----|----|----|----|----| HIGH

Temporal demand LOW |----|----|----|----|----|----|----|----|----|----| HIGH

Frustration level LOW |----|----|----|----|----|----|----|----|----|----| HIGH

Effort LOW |----|----|----|----|----|----|----|----|----|----| HIGH

Performance POOR |----|----|----|----|----|----|----|----|----|----| GOOD

SEGMENT OF MISSION: **First waypoint to release point**

Mental demand LOW |----|----|----|----|----|----|----|----|----|----| HIGH

Physical demand LOW |----|----|----|----|----|----|----|----|----|----| HIGH

Temporal demand LOW |----|----|----|----|----|----|----|----|----|----| HIGH

Frustration level LOW |----|----|----|----|----|----|----|----|----|----| HIGH

Effort LOW |----|----|----|----|----|----|----|----|----|----| HIGH

Performance POOR |----|----|----|----|----|----|----|----|----|----| GOOD

SEGMENT OF MISSION: **Recce zone [release point to target]**

Mental demand	LOW	|----|----|----|----|----|----|----|----|----|----|	HIGH
Physical demand	LOW	|----|----|----|----|----|----|----|----|----|----|	HIGH
Temporal demand	LOW	|----|----|----|----|----|----|----|----|----|----|	HIGH
Frustration level	LOW	|----|----|----|----|----|----|----|----|----|----|	HIGH
Effort	LOW	|----|----|----|----|----|----|----|----|----|----|	HIGH
Performance	POOR	|----|----|----|----|----|----|----|----|----|----|	GOOD

SEGMENT OF MISSION: **Egress [target to END]**

Mental demand	LOW	|----|----|----|----|----|----|----|----|----|----|	HIGH
Physical demand	LOW	|----|----|----|----|----|----|----|----|----|----|	HIGH
Temporal demand	LOW	|----|----|----|----|----|----|----|----|----|----|	HIGH
Frustration level	LOW	|----|----|----|----|----|----|----|----|----|----|	HIGH
Effort	LOW	|----|----|----|----|----|----|----|----|----|----|	HIGH
Performance	POOR	|----|----|----|----|----|----|----|----|----|----|	GOOD

ANNEX C

Post Mission Questionnaires

Summary of Post Mission Questionnaires
TAMSS Project - Experiment 2

Flying Pilot

Rated Performance

M1. Rate how well you performed of each of the following tasks during this mission. Circle N/A if the item was not applicable to this mission.

Average scores; poor (1-3), adequate (4) and good (5-7)

Average score for rated performance overall; hand map alone = 4.3, moving map = 4.5, moving map and sensor = 4.9

	Hand map only	Moving map	Moving map and sensor
Finding waypoints	Good (4.5)	Good (4.33)	Good (5)
Control heading	Good (4.5)	Good (4.75)	Good (5)
Control altitude	Adequate (4)	Good (4.5)	Good (4.75)
Control airspeed	Adequate (4)	Adequate (4)	Good (4.5)
Cross checking relevant instrument/symbology	Good (4.5)	Good (4.5)	Good (5)
Using information from the external scene to control the aircraft	Good (4.5)	Good (4.5)	Good (4.75)
Positioning the aircraft in recce area	Adequate (4.25)	Good (4.75)	Good (5.25)
Maintaining tactical flight	Good (4.5)	Good (4.75)	Good (5.25)

Rated Task Difficulty

M2. Rate the difficulty of each of the following tasks during the mission. Circle N/A if the item was not applicable to this mission.

Average scores; easy (1-3), moderate (4) and difficult (5-7)

Average score for rated difficulty overall; hand map alone = 3.35, moving map = 2.7, moving map and sensor = 2.6

	Hand map only	Moving map	Moving map and sensor
Finding waypoints	Difficult (4.33)	Easy (2.5)	Easy (2.67)
Control heading	Easy (3.75)	Easy (2.5)	Easy (2.25)
Control altitude	Moderate (4)	Easy (2.5)	Easy (2.25)
Control airspeed	Easy (2.5)	Easy (3)	Easy (2.75)
Cross checking relevant instrument/symbology	Easy (2.5)	Easy (2.75)	Easy (2.75)
Using information from the external scene to control the aircraft	Easy (3.5)	Easy (2.75)	Easy (2.5)
Positioning the aircraft in recce area	Easy (3.25)	Easy (3)	Easy (2.5)
Maintaining tactical flight	Easy (3)	Easy (2.75)	Easy (3)

Rated Situation Awareness

M3. Rate your awareness of the status of the aircraft systems as it applies to your mission/task.

Average scores; low (1-3), moderate (4) and high (5-7)

Average score for rated awareness of system's status overall; hand map alone = 4.57, moving map = 4.65, moving map and sensor = 4.9

	Hand map alone	Moving map	Moving map and sensor
Aircraft systems overall	Moderate (3.33)	Moderate (4.25)	Moderate (4.25)
Heading	High (4.75)	High (4.5)	High (5)
RAD alt	High (5)	High (5)	High (5.5)
Airspeed	High (5)	High (4.75)	High (5)
Attitude	High (4.75)	High (4.75)	High (4.75)

M4. Rate your awareness of tactical information relevant to your mission (i.e. where do you need to go and what needs to be completed, mission goals and how is the mission unfolding).

Average scores; low (1-3), moderate (4) and high (5-7)

Average score for rated awareness of mission overall; hand map alone = 4.2, moving map = 4.4, moving map and sensor = 4.7

	Hand map alone	Moving map	Moving map and sensor
Overview of mission	High (4.75)	High (4.5)	High (5)
Unfolding of mission/keeping track of how mission unfolds	Moderate (4)	High (4.75)	High (4.5)
Potential developments (anticipating future scenarios)	High (4.5)	Low (3.75)	High (4.5)
Global mission goals	High (4.5)	High (4.5)	High (4.75)
Specific mission goals	High (5)	High (4.75)	High (4.75)
Enemy activities	Low (3.5)	High (4.5)	High (5)
Friendly activities	Low (3.75)	Low (3.75)	Moderate (4.5)
General threat	Moderate (4.25)	Moderate (4.25)	High (4.5)
Where I need to go	Low (3.75)	High (5)	High (4.75)

M5. Rate your spatial/navigational awareness (i.e. where you need to go and location of ownship in relation to enemies, friendly units, target and other relevant objects and landmarks in the environment).

Average scores; low (1-3), moderate (4) and high (5-7)

Average score for rated awareness of mission overall; hand map alone = 3.9, moving map = 4.2, moving map and sensor = 4.4

	Hand map alone	Moving map	Moving map and sensor
Overall spatial orientation	High (4.5)	Moderate (4.25)	High (4.75)
Ownship location in relation to target (e.g. bridge)	Moderate (4.25)	High (4.5)	High (4.5)
Ownship location in relation to enemy activity	Moderate (4)	Moderate (4.25)	High (4.5)
Ownship location in relation to friendly activity	Low (3.75)	Low (3.5)	Low (3.75)
Target location relative to enemy and friendly units	Low (3.75)	Moderate (4.25)	Moderate (4)
Important landmarks	Low (3.25)	Moderate (4.25)	High (4.5)
General layout of the navigated area	Low (3.75)	High (4.5)	High (4.5)

M6. Rate the following crew activity.

Average score for rated awareness of crew activity overall ; hand map alone = 4.75, moving map = 4.5, moving map and sensor = 4.625

	Hand map alone	Moving map	Moving map and sensor
Overall quality of communication	High (4.5)	Moderate (4.25)	Moderate (4.25)
The usefulness of information provided by Mission Commander	High (5)	High (4.75)	High (5)

Rated Workload

M7. Rate your workload during this mission. Circle NA if not applicable for this mission.

Average score for rated workload overall; hand map alone = 3, moving map = 2.95, moving map and sensor = 2.9

	Hand map alone	Moving map	Moving map and sensor
Ingress to first waypoint	Low (2.25)	Low (2)	Low (2)
First waypoint to release point	Low (2.75)	Low (2.75)	Low (2)
Recce zone [release point to target]	Moderate (4)	Low (3.5)	Moderate (4.25)
Egress [target to end]	Low (3)	Low (2.5)	Low (3)
Overall	Low (3.25)	Moderate (4)	Low (3.25)

Additional question: At any point did you find that your workload was very different (e.g. much higher or lower) than across the mission as a whole?

P1: During enemy engagement in vicinity of objectives
P3: Higher workload when hovering the simulator

Summary of Post Mission Questionnaires
TAMSS Project - Experiment 2

Mission Commander

Rated Confidence in Re-creating Mission

M1. Please re-create the mission you flew using your mission map. Using numbers, indicate the orders of waypoints/landmarks visited: show the flight path with lines. Identify the activity that takes place during the mission. Indicate where it takes place. After you have finished re-creating this mission, rate your confidence in the accuracy of your re-creation of this mission.

Average rated confidence overall; hand map alone = 4.13, moving map = 4.6, moving map and sensor = 4.75

	Hand map alone	Moving map	Moving map and sensor
Re-creating the flight path in the recce zone	High (4.75)	High (5)	High (5)
Identifying activity along the flight path **IN** the recce zone	Low (3.75)	Moderate (4.25)	High (4.75)
Identifying activity along the flight path **before** the recce zone	Low (4)	High (4.5)	High (4.5)
Overall	Moderate (4)	High (4.5)	High (4.75)

Participants' additional comments

P1: When manoeuvring under enemy fire it is difficult to re-create the path.
P1: Definitely more difficult to re-create mission on a paper map when mission was executed using a digital map.
P2: Very difficult to identify activity without sensors.
P4: Very easy to identify terrain with the SA provided by the moving map display. Differences between moving map and paper map may cause some confusion.

Rated Performance

M2. Rate how well you performed of each of the following tasks during this mission. Circle N/A if the item was not applicable to this mission.

Average scores; poor (1-3), adequate (4) and good (5-7)
Average rated performance overall; hand map alone = 4.4, moving map = 5.1, moving map and sensor = 5.0

	Hand map only	Moving map	Moving map and sensor
Finding waypoints	Poor (3.33)	Good (5.25)	Good (5.5)
Using the CDU	Good (4.67)	Good (4.75)	Good (5.25)
Reading the map	Adequate (4.25)	Good (5.25)	Good (5)
Using the map to navigate	Good (4.5)	Good (5.5)	Good (5.25)
Planning the route	Good (4.75)	Good (5)	Good (4.75)
Using comms	Good (4.75)	Adequate (4.25)	Good (4.5)
Communicating with the ERSTA operator			Good (5.25)
Guiding the ERSTA operator to position the sensor			Good (4.5)
Guiding the flying pilot to position the aircraft in recce zone	Good (4.5)	Good (5.67)	Good (5)

Rated Task Difficulty

M3. Rate the difficulty of each of the following tasks during the mission. Circle N/A if the item was not applicable to this mission.

Average scores; easy (1-3), moderate (4) and difficult (5-7)
Average rated difficulty overall; hand map alone = 4.14, moving map = 2.75, moving map and sensor = 2.6

	Hand map only	Moving map	Moving map and sensor
Finding waypoints	Difficult (5.33)	Easy (2.75)	Easy (2)
Using the CDU	Easy (3.67)	Easy (2.75)	Easy (2.5)
Reading the map	Difficult (4.5)	Easy (2.75)	Easy (2.5)
Using the map to navigate	Moderate (4.25)	Easy (2.75)	Easy (2.75)
Planning the route	Moderate (4)	Easy (2.75)	Easy (2.5)
Using comms	Easy (3)	Easy (3.5)	Easy (2.75)
Communicating with the ERSTA operator			Easy (2.5)
Guiding the ERSTA operator to position the sensor			Easy (2.75)
Guiding the flying pilot to position the aircraft in recce zone	Moderate (4.25)	Easy (2)	Easy (2.75)

M4. Rate the difficulty of getting information from each of the following sources during this mission. Circle NA if not applicable to this mission.

Average scores; easy (1-3), moderate (4) and difficult (5-7)

Overall rated difficulty of getting information; hand map alone = 3.71, moving map = 2.8, moving map and sensor = 2.45

	Hand map alone	Moving map	Moving map and sensor
Hand map	Easy (3.75)	Easy (3)	Easy (2)
Moving map		Easy (2.5)	Easy (2.5)
ERSTA sensor			Easy (2.5)
ERSTA operator			Easy (2.25)
CDU	Easy (3.67)	Easy (3)	Easy (3)

Rated Situation Awareness

M5. Rate your awareness of tactical information relevant to your mission (i.e. where do you need to go and what needs to be completed, mission goals and how is the mission unfolding).

Average scores; poor (1-3), moderate (4) and high (5-7)
Overall rated awareness of mission; hand map alone = 4.86, moving map = 4.56, moving map and sensor = 5.31

	Hand map alone	Moving map	Moving map and sensor
Overview of mission	High (5.25)	High (4.75)	High (5.25)
Unfolding of mission/keeping track of how mission unfolds	High (4.75)	High (4.75)	High (5.75)
Potential developments (anticipating future scenarios)	High (4.75)	High (4.5)	High (5.75)
Global mission goals	High (4.5)	Moderate (4.25)	High (5)
Specific mission goals	High (5)	High (5)	High (5.5)
Enemy activities	High (4.5)	Moderate (4)	High (5)
Friendly activities	High (4.5)	Moderate (4.25)	High (5.25)
General threat	High (5.25)	Moderate (4.25)	High (4.75)
Where I need to go	High (5.25)	High (5.25)	High (5.5)

M6. Rate your spatial/navigational awareness (i.e. where you need to go and location of ownship in relation to enemies, friendly units, target and other relevant objects and landmarks in the environment).

Average scores; poor (1-3), moderate (4) and high (5-7)
Overall rated spatial awareness; hand map alone = 3.93, moving map = 4.75, moving map and sensor = 5.75

	Hand map alone	Moving map	Moving map and sensor
Overall spatial orientation	Moderate (4)	High (5.25)	High (5.5)
Ownship location in relation to target (e.g. bridge)	High (4.75)	High (5.25)	High (6)
Ownship location in relation to enemy activity	Low (3.5)	Moderate (4.25)	High (5.5)
Ownship location in relation to friendly activity	Moderate (4)	Moderate (4)	High (6)
Target location relative to enemy and friendly units	Moderate (4)	High (4.5)	High (5.75)
Important landmarks	Low (3.5)	High (4.75)	High (5.5)
General layout of the navigated area	Low (3.75)	High (5.25)	High (6)

M7. Rate the following crew activity.

Average scores; poor (1-3), moderate (4) and high (5-7)
Overall rated crew awareness/activity; hand map alone = 4.5, moving map = 4.625, moving map and sensor = 5.5

	Hand map alone	Moving map	Moving map and sensor
Overall quality of communication	Moderate (4.25)	Moderate (4.25)	High (5.5)
The usefulness of information provided by ERSTA officer			High (5.75)
Ability to instruct ERSTA operator			High (5.25)
Awareness of ERSTA operator's activity			High (5.75)
Ability to convey information to flying pilot	High (4.75)	High (5)	High (5.25)

Rated Workload

M7. Rate your workload during this mission. Circle NA if not applicable for this mission.

Average rated workload overall; hand map alone = 3.95, moving map = 3.3, moving map and sensor = 3.1

	Hand map alone	Moving map	Moving map and sensor
Ingress to first waypoint	Low (3.5)	Low (2.5)	Low (2)
First waypoint to release point	Moderate (4.25)	Low (2.75)	Low (2.5)
Recce zone [release point to target]	High (4.75)	Low (3.75)	Moderate (4)
Egress [target to end]	Low (3)	Moderate (4)	Low (3.67)
Overall	Moderate (4.25)	Low (3.5)	Low (3.5)

Additional question: At any point did you find that your workload was very different (e.g. much higher or lower) than across the mission as a whole?

Paper map condition: YES(4) NO(0)

P1: During the actual recce due to the number of agencies needed to be contacted on different frequencies.

P2: High workload in recce zone – mainly associated with trying to maintain SA of own location.

Moving map condition: YES(2) NO(2)

P1: Workload is higher in the recce zone.

P4: During observation of the OBJ, the workload for the MC is more demanding because of the requirements for continuous communications with various call signs

Moving map/sensor condition: YES(2) NO(2)

P2: Busier at OPs because able to see more. Moving map reduces workload related to navigation freeing more time for msn work (comms, search etc.)

P4: During the engagement period of the EN vehicles. The COMMS was demanding causing heavier workload the rest of the mission.

ANNEX D
Background Questionnaire

TAMSS Experiment 2 **Participant ID: __________**

Background Information

This information helps us to determine whether we have recruited a broad sample of pilots. To get an unbiased understanding of the concerns of the operation community, we must get feedback from a cross-section of experience levels and backgrounds.

1. Age: ___________ (in years)
2. Years in CF: ___________
3. Years as a pilot: ________
4. Handedness: ____left OR ___ right

Estimated Flight Time

Type of Flight	**Estimated time (in hours)**
1. Total flight time	
2. Total rotary wing	
3. Total Griffon	
4. Total time flying with ERSTA	
5. Time spent using a flight simulator	
6. How familiar are you with the Gagetown area (very….not at all)?	

Specify the type of simulator experiences that you have had:

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Indicate any other flight experience that you believe may be relevant to your performance in this experiment.

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ANNEX E

CSE Ratings: Hand vs. Moving Map for Flying Pilot

TAMSS Experiment 2 **Participant ID: ______________________**

DAY 1: Hand Map Alone versus Moving Map comparison

FLYING PILOT VERSION

Rate the impact of having a hand map alone as compared to a moving map on your experiences in the simulator. Circle your response for each item. A rating of '4' means there was no difference between the hand map alone and moving map conditions.

	COMPARISON							
	Hand Map Alone much better than **Moving Map**			No difference			**Moving Map** much better than **Hand Map Alone**	
1. Overall situation awareness	1	2	3	4	5	6	7	NA
2. Overall mission awareness	1	2	3	4	5	6	7	NA
3. Awareness of spatial orientation	1	2	3	4	5	6	7	NA
4. Awareness of activities (enemies, friendly units)	1	2	3	4	5	6	7	NA
5. Anticipating future events	1	2	3	4	5	6	7	NA
6. Using information from the scene to control the aircraft	1	2	3	4	5	6	7	NA
7. Awareness of heading	1	2	3	4	5	6	7	NA
8. Communication from Mission Commander	1	2	3	4	5	6	7	NA
9. Communication to Mission Commander	1	2	3	4	5	6	7	NA
10. Low-level flight	1	2	3	4	5	6	7	NA

11. Low-level maneuvering	1	2	3	4	5	6	7	NA
12. Maintaining heading	1	2	3	4	5	6	7	NA

TAMSS Experiment 2 **Participant ID:**

____

DAY 2: Hand Map Alone versus Moving Map+Sensor comparison

FLYING PILOT VERSION

Rate the impact of having a hand map alone as compared to a moving map and the sensor on your experiences in the simulator. Circle your response for each item. A rating of '4' means there was no difference between the hand map alone and the moving map + sensor conditions.

	COMPARISON							
	Hand Map Alone much better than **Moving Map+Sensor**			No difference			**Moving Map+Sensor** much better than **Hand Map Alone**	
1. Overall situation awareness	1	2	3	4	5	6	7	NA
2. Overall mission awareness	1	2	3	4	5	6	7	NA
3. Awareness of spatial orientation	1	2	3	4	5	6	7	NA
4. Awareness of activities (enemies, friendly units)	1	2	3	4	5	6	7	NA
5. Anticipating future events	1	2	3	4	5	6	7	NA
6. Using information from the scene to control the aircraft	1	2	3	4	5	6	7	NA
7. Awareness of heading	1	2	3	4	5	6	7	NA
8. Communication from Mission Commander	1	2	3	4	5	6	7	NA
9. Communication to Mission Commander	1	2	3	4	5	6	7	NA
10. Low-level flight	1	2	3	4	5	6	7	NA
11. Low-level maneuvering	1	2	3	4	5	6	7	NA
12. Maintaining heading	1	2	3	4	5	6	7	NA

13. Anticipating future events	1	2	3	4	5	6	7	NA
14. Completing the mission	1	2	3	4	5	6	7	NA

ANNEX F

CSE Ratings: Hand vs. Moving Map for Mission Commander

DAY 1: Hand Map Alone versus Moving Map comparison

MISSION COMMANDER VERSION

Rate the impact of having a hand map alone as compared to a moving map on your experiences in the simulator. Circle your response for each item. A rating of '4' means there was no difference between the hand map alone and moving map conditions.

	COMPARISON							
	Hand Map Alone much better than **Moving Map Alone**			No difference			**Moving Map** much better than **Hand Map Alone**	
15. Overall situation awareness	1	2	3	4	5	6	7	NA
16. Keeping track of activity (enemies, friendly units)	1	2	3	4	5	6	7	NA
17. Overall spatial orientation	1	2	3	4	5	6	7	NA
18. Using the map to navigate	1	2	3	4	5	6	7	NA
19. Planning the route	1	2	3	4	5	6	7	NA
20. Reading the map	1	2	3	4	5	6	7	NA
21. Using the CDU	1	2	3	4	5	6	7	NA
22. Using comms	1	2	3	4	5	6	7	NA
23. Communication to flying pilot	1	2	3	4	5	6	7	NA
24. Communication from flying pilot	1	2	3	4	5	6	7	NA
25. Communication to ERSTA operator	1	2	3	4	5	6	7	NA
26. Communication from ERSTA operator	1	2	3	4	5	6	7	NA
27. Eyes out time	1	2	3	4	5	6	7	NA
28. Overall mission awareness	1	2	3	4	5	6	7	NA

29. Anticipating future events	1	2	3	4	5	6	7	NA
30. Completing the mission	1	2	3	4	5	6	7	NA

TAMSS Experiment 2 **Participant ID: _______________________**

DAY 2: Hand Map Alone versus Moving Map+Sensor comparison
MISSION COMMANDER VERSION

Rate the impact of having a hand map alone compared to a moving map and sensor on your experiences in the simulator. Circle your response for each item. A rating of '4' means there was no difference between the hand map alone and moving map + sensor conditions.

	COMPARISON							
	Hand Map Alone much better than **Moving Map +Sensor**			No difference			**Moving Map+Sensor** much better than **Hand Map Alone**	
1) Overall situation awareness	1	2	3	4	5	6	7	NA
2) Keeping track of activity (enemies, friendly units)	1	2	3	4	5	6	7	NA
3) Overall spatial orientation	1	2	3	4	5	6	7	NA
4) Using the map to navigate	1	2	3	4	5	6	7	NA
5) Planning the route	1	2	3	4	5	6	7	NA
6) Reading the map	1	2	3	4	5	6	7	NA
7) Using the CDU	1	2	3	4	5	6	7	NA
8) Using the comms	1	2	3	4	5	6	7	NA
9) Communication to flying pilot	1	2	3	4	5	6	7	NA
10) Communication from flying pilot	1	2	3	4	5	6	7	NA
11) Communication to ERSTA operator	1	2	3	4	5	6	7	NA
12) Communication from ERSTA operator	1	2	3	4	5	6	7	NA

13) Eyes-out time	1	2	3	4	5	6	7	NA
14) Overall mission awareness	1	2	3	4	5	6	7	NA
15) Anticipating future events	1	2	3	4	5	6	7	NA
16) Completing the mission	1	2	3	4	5	6	7	NA

ANNEX G
Summary of Final Questionnaire

Summary of Final Questionnaire
TAMSS Project - Experiment 2

Flying Pilot Role

Paper map alone versus moving map

Overall situation awareness	5.33
Overall mission awareness	5.33
Awareness of spatial orientation	5.67
Awareness of activities enemies, friendly units)	4.33
Anticipating future events	3.67
Using information from the scene to control the aircraft	5.33
Awareness of heading	6
Communication from Mission Commander	5.33
Communication to Mission Commander	5.33
Low-level flight	5.67
Low-level maneuvering	5
Maintaining heading	5.67

1 = hand map alone much better, 4 = no difference, 7 = moving map much better

Paper map alone versus moving map and sensor

Overall situation awareness	5
Overall mission awareness	5
Awareness of spatial orientation	5
Awareness of activities (enemies, friendly units)	5
Anticipating future events	4.33
Using information from the scene to control the aircraft	5.33
Awareness of heading	4
Communication from Mission Commander	5.33
Communication to Mission Commander	4.67
Low-level flight	5
Low-level maneuvering	4.67
Maintaining heading	4.33

1 = hand map alone much better, 4 = no difference, 7 = moving map and sensor much better

Mission Commander Role

Paper map alone versus moving map

Overall situation awareness	5.33
Keeping track of activity (enemies, friendly units)	3.67
Overall spatial orientation	5.67
Using the map to navigate	6.67
Planning the route	4.33
Reading the map	5
Using the CDU	3.33
Using comms	4.67
Communication to flying pilot	5
Communication from flying pilot	4
Communication to ERSTA officer	NA
Communication from ERSTA officer	NA
Eyes out time	5.33
Overall mission awareness	5.33
Anticipating future events	4.67
Completing the mission	5.33

1 = hand map alone much better, 4 = no difference, 7 = moving map much better

Paper map alone versus moving map and sensor

Overall situation awareness	6.33
Keeping track of activity (enemies, friendly units)	5.67
Overall spatial orientation	6
Using the map to navigate	5.67
Planning the route	4
Reading the map	5.33
Using the CDU	4.33
Using comms	4.33
Communication to flying pilot	5.67
Communication from flying pilot	4.33
Communication to ERSTA officer	5.67
Communication from ERSTA officer	5.67
Eyes out time	4
Overall mission awareness	6.33
Anticipating future events	5.33
Completing the mission	6.33

1 = hand map alone much better, 4 = no difference, 7 = moving map and sensor much better

Annex G – Report 4: Experiment 3

Centre for Applied Cognitive Research

Carleton University

Using a Cognitive Systems Framework as a Guide for Modelling and Simulation Programs

The Impact of a Mission Specialist on the Situation Awareness, Workload and Performance of the CH-146 Mission Commander

TAMSS SA PROJECT

Report on Experiment 3

Dr. C. M. Herdman

31 March 2004

Contract Serial No. 007SV-W7714-010547

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31 March 2003

Contract Serial Number 007SV-W7714-010547

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This study, approved by the Carleton University Ethics Committee for Psychological Research, was conducted in conformity with the Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans.

Using a Cognitive Systems Framework as a Guide for Modelling and Simulation Programs

The Impact of a Mission Specialist on the Situation Awareness, Workload and Performance of the CH-146 Mission Commander

Centre for Applied Cognitive Research
March 31, 2004

EXECUTIVE SUMMARY

As part of the Department of National Defence (DND) Tactical Aviation Mission System Simulation (TAMSS) Situation Awareness initiative, the Centre for Applied Cognitive Research (CACR) at Carleton University has proposed a Cognitive Systems Engineering (CSE) framework to be used as a guide for conducting and interpreting evaluations in Modelling and Simulation (M&S) programs. The present document is a report on Experiment 3 (E3) of the TAMSS SA program.

Experiment 3 of the TAMSS SA program had three major activities. The first activity was to further integrate and extend the DND CH-146 ERSTA-like model and control capabilities with the simulator facility at the CACR. The second major activity was to provide a more stable HLA-based distributed simulation environment, including refinements to the data collection capabilities of the CACR simulator facility. The third major activity was to conduct a study to further test the CSE framework by examining the performance, situation awareness (SA) and workload of the CH-146 Mission Commander (MC) under conditions where a Mission Specialist (MS) was present versus a conditions were a Mission Specialist was not present.

Experiment 3 clearly demonstrates the advantage of using the CSE framework for M&S programs. The CSE framework provided a comprehensive set of measures that allowed a broad overview of how the MS affected the task. Furthermore, the use of both subjective and objective measures of SA, workload, and performance allowed confirmation across the various aspects of the situation. Specifically, the results provide a clear picture of how the presence of a mission specialist affected the subjective and objective task performance. In particular, the MC, freed

from the increased demands of operating the sensor, had more mental attention to put towards the primary demands of the MC role.

The experiment was also technically progressive. The DND ERSTA-like model was successfully extended and provided the requisite level of functionality to enable the aircrew to use the digital moving map and the sensor capabilities in a realistic and appropriate manner. The distributed simulation environment was robust and stable: The High-Level Architecture (HLA) simulation which connected the ERSTA system model to the flight simulator ran flawlessly for eight-ten hours per day across twelve days. Furthermore, the complete suite of data collection utilities was stable and accurate throughout the experiment.

It is important to note that the ERSTA-like model that was used in this experiment was intended to represent the primary functionality of the ERTSA system that has been specified as a possible technology for the CH-146 Griffon. <u>However, the ERTSA-like model that was developed was not intended as a prototype ERSTA system. The ERSTA-like model was not intended to provide the full functionality and capability that has been specified for the CH-146 ERTSA system</u>. For example, the magnification (zoom) in the ERSTA-like model was significantly less than that specified for the ERSTA system. In addition, thermal imaging was not modeled: only a camera sensor was provided. Finally, while the sensor controls were reasonably close to what might be expected for the MS station, the sensor controls that were provided to the MC were not intended to match the controls that would be acquired in the CH-146 ERSTA program.

It is concluded that the CSE framework and the simulation environment that was developed in the TAMSS SA project can be used to affect the design, prototype, test, build and implementation processes in simulation-based acquisition programs.

REVISION PAGE

REVISION LETTER	PAGES AFFECTED	DATE	APPROVAL

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1 Background

This document is a report on Experiment 3 (E3) of the TAMSS SA program. The primary goal of this experiment was to exercise and evaluate a Cognitive System Engineering (CSE) framework for assessing the impact of novel technology on aircrew in the CH-146 Griffon helicopter.

The current experiment follows from Experiment 2 (E2) of the Tactical Aviation Mission System Simulation (TAMSS) Situation Awareness (SA) project. In E2, CH-146 Griffon aircrew consisting of a Flying Pilot (FP) and a Mission Commander (MC) completed a series of zone reconnaissance (recce) missions. Of primary interest was how an ERSTA-like system, including a digital moving map and a sensor capability, affected the performance, situation awareness and workload of the MC during the execution of the missions.

Three conditions were compared in E2:

- Paper Map (P-Map).

  This was a baseline condition to reflect the current situation in the Griffon where aircrew (i.e., the MC) navigate using a hand-held paper map and detect and identify targets without aid of a sensor.

- Moving Map (M-Map)

  In this condition, the MC was provided with a digital moving map positioned on the MC's leg/lap. A paper map was also provided for use at the discretion of the MC. As in the paper map condition, the aircrew performed the missions without the aid of the ERSTA-like sensor.

- Moving Map plus Sensor (M-Map/Sensor)

  In this condition, both the digital moving map (and the paper map) and the ERSTA-like sensor capability were provided to the MC. The sensor (camera) image was displayed on the front centre console in the position where the Griffon FLIR image is normally located. In this condition, the MC was able to use the sensor image to support target detection and identification.

The results from E2 showed that the ERSTA-like system (digital moving map and sensor) added significant capability to Griffon aircrew. Participant ratings indicated that the digital moving map and sensor enhanced the MC's performance and SA while lowering task difficulty and workload. There was some indication of these benefits being transferred to the FP, particularly in terms of the aircrew's ability to position the aircraft and to maintain tactical flight. In addition, head tracking data showed that relative to the P-Map condition, the MC was able to spend more time looking up and out of the cockpit in the M-Map and M-Map/Sensor conditions.

Experiment 2 of the TAMSS SA project provided a solid foundation for developing the current experiment. Of importance in E2 was that (a) a base-level ERSTA-like system was effectively modeled and integrated into the simulator environment using High-Level Architecture (HLA) protocol, (b) the scenarios that were developed represented realistic and workable tactical missions, and (c) the questionnaire battery developed for obtaining subjective measures proved to be sufficiently sensitive such that differences in performance, SA, and workload could be detected across the three experimental conditions.

2 Introduction to Present Experiment

The primary goal of this experiment was to exercise and evaluate a Cognitive System Engineering (CSE) framework for assessing the impact of novel technology on aircrew in the CH-146 Griffon helicopter. Trained CH-146 aircrew completed a series of recce missions. On half of the missions the crew included a Flying Pilot (FP), Mission Commander (MC), and a Mission Specialist (MS). On the other half of the missions, the MS was not included. Of interest was how the presence versus absence of the MS affected the performance, situation awareness, and workload of the CH-146 MC while completing the recce missions.

2.1 Major activities

The conduct of Experiment 3 consisted of three major activities. The first two major activities involved simulation engineering to enhance the ERSTA-like system that was modeled and used in the experiment and to significantly improve the stability and data collection facility of the simulation environment. The third major activity was to design and conduct the experiment.

2.1.1 Extend ERSTA-like model

The first major activity was to extend the functionality and control capabilities of the ERSTA-like system beyond those that were initially modeled in E2 and to enhance the integration of this model with the simulation environment. A summary of the ERSTA-like system, hardware and software architecture is presented in the TAMSS SA final report.

Extending the ERSTA-like system included modifying the model that was used in Experiment 2 (E2) to provide:

- additional functionality to the digital moving map display, including a military grid overlay for the digital map, touch accessible grid read-out capabilities from the digital moving map, and user options for using North-up versus heading-up orientation, and

- control capability of the sensor image for the Mission Commander (MC).

2.1.2 Enhance stability of simulation environment.

The second major activity in E3 was to improve the stability and utility of the simulation environment. The hardware and simulation architecture of the simulation environment as well as the development and issues surrounding data collection in a distributed system are presented in the TAMSS SA final report.

The enhancements to the simulation environment included:

- improving the fundamental stability and performance of the ERSTA-like model,
- stabilizing the flight simulator through programming upgrades and modification of the core simulation and HLA software,
- further integration of the ERTSA-like model and the flight simulator, and
- improvements to the data collection capabilities within the distributed simulation environment.

2.1.3 Design, conduct and analysis of experiment

The third major activity was to design, conduct and analyze the experiment. The primary goal of this experiment was to determine whether the CSE framework could be used to measure the impact of the ERSTA-like system on the CH-146 aircrew, and in particular, on the performance, SA, and workload of the CH-146 MC. To this end, the following two conditions were compared in this experiment:

- <u>Mission Specialist Present</u>. In this condition, the crew included a Mission Commander (MC), Flying Pilot (FP), and a Mission Specialist (MS). The MS assumed primary operation of the ERSTA-like system, in and particular, the sensor. The MC was able to view and interact with the digital moving map and if desired, take control of the sensor.
- <u>No Mission Specialist Present</u>. In this condition, the crew consisted of the MC and FP. A MS was not present. In this condition, the MC assumed responsibility for operating the ERSTA-like system.

The conduct of E3 was enabled by the major engineering activities, as describe above. In addition, E3 was supported by the following activities:

- input from Subject Matter Experts (SME) regarding the functionality and use of the ERSTA-like system as well as how mission specialists could be integrated into the CH-146 aircrew,
- modification of the tactical scenarios that were used in E2 of the TAMSS SA project in order to provide Fire Mission Support (FMS) capabilities in the scenarios,
- development of tactical knowledge and the expertise to allow for dynamic control of elements by the experimenters during the missions, including the escalation of enemy activity, and
- modifications of the questionnaire battery from E2 that were used for obtaining subjective ratings of performance, situation awareness, and workload.

3 Method

3.1 Participants: Pilots

The background questionnaire for the pilots is shown in Annex C. Participants were 7 male pilots and 1 female pilot from the Canadian Forces ranging in age from 30 to 48 years (M = 40.125). Years in the Canadian Forces ranged between 11 and 29 years (M = 20). Years as a pilot ranged between 5 and 26 years (M =18.5). Six of the eight pilots were right handed and two pilots were left-handed. All eight participants had some experience with flight simulators. These included full motion CH-146, CH-135, AH-64, and VH-1 simulators, CT-114 Tutor Procedures Trainer, AH-64, Bell 205/212/412, Griffon Beech 1900D, Dash 8, Airbus 320, and Boeing 737. The following table summarizes the pilots' estimated time in hours for various types of flights.

	Estimated Time (hours)	
Type of Flight	**Range**	**Mean**
Total flight time	1500 - 9000	4375
Total rotary wing	1200 - 7000	3456
Total Griffon	6 - 2500	1182
Time spent using a flight simulator	50 - 300	156

3.2 Participants: Mission Specialists

The background questionnaire for the mission specialists is shown in Annex D). Mission specialists were 2 males from the Canadian Forces aged 44 and 46 years. They had spent 25 and 28 years in the Canadian Forces, with 1 and 4 years of experience as mission specialists. Both were right handed. Both of these participants had some experience with flight simulators. These included 7A/7B simulators. The following table summarizes the mission specialists' estimated time in hours for various times of flights.

	Estimated Time (hours)	
Type of Flight	**Range**	**Mean**
Total rotary wing	45 - 1700	873
Total Griffon	45 - 55	50
Time spent using a flight simulator	70	70

3.3 Measures

In Experiments 1 and 2 of the TAMSS SA project, it was demonstrated that pilot's self ratings of their performance, SA and workload can provide a reasonable index concerning the impact of a new cockpit technology (i.e., HUD). Moreover, in E1 it was demonstrated that SA could be objectively assessed by measuring a pilot's ability to detect and report airborne (e.g., other aircraft) and ground entities (e.g., tanks, downed aircraft) while performing a mission. An important finding from E1 was that this objective measure revealed significant and differences in SA even in conditions where the pilots' subjective ratings of SA were not different.

In the present experiment, all three dimensions of behaviour outlined in the CSE framework were measured subjectively: performance, workload, and situation awareness. (See Table 3.3 below). In addition, a focus was placed on obtaining an objective measure of workload as well as objective measures of performance/behaviour.

TABLE 3.3 CSE MEASURES

	Type of Measure	
CSE Domain	**Objective**	**Subjective**
Task-Relevant Performance/Behaviour	Head positioning of MC Use of sensor	Ratings of performance
Situation Awareness	Detection of airborne and ground objects	Ratings of SA (specific and global)
Workload	Detection of visual stimuli	Ratings of workload

3.3.1 Task-relevant performance measure

- Subjective ratings. Following each mission, the FP and the MC completed subjective ratings of performance in the mission. These rating questionnaires are shown in Annex B.

- Objective measure 1: Head-down time. One objective measure was the head-positioning of the MC. It was hypothesized that when a MS was included in the crew, the MS would be given primary responsibility for operating the ERSTA-like sensor. For missions where the crew did not include a MS, the MC was required to control the sensor image. It was predicted, therefore, that MCs would spend less time with their heads down and inside the cockpit when a MS was present as compared to when a MS was not present.

- Objective measure 2: Sensor time. A second objective measure of task-relevant performance was the amount of time the sensor was used throughout a mission. It was predicted that the crew's use of the sensor would be greater when a MS was present. When a MS was not present, the MC would have limited time available for controlling the sensor.

3.3.2 Situation awareness measures

- Subjective ratings. Situation awareness was measured subjectively in this experiment by having the FP and MC complete Likert-scale ratings of SA after each mission (see Annex B)

- Objective measures. Objective measures of SA were not obtained (but see E1 of the TAMSS project).

3.3.3 Workload measures

- Subjective ratings. Following each mission, the FP and MC completed separate Likert-scale questionnaires of workload as well as workload ratings based on a modified NASA TLX. Subjective ratings for global workload were obtained as were ratings for specific segments (e.g., ingress, recce-zone, egress) in the missions (see Annex B).

- Objective measure. Workload was objectively assessed using a visual detection task whereby the MC was required to indicate when they detected a visual target (a briefly displayed green circle) on the front screen. The targets subtended approximately 2 deg of visual angle and were presented every 15 sec (+/- 3 sec randomly determined) throughout the workload missions.

3.4 Materials

The crew completed realistic zone-recce missions (see descriptions in Annex A). For each mission, a primary objective was defined and details were given concerning the flight path leading to the Release Point (RP). Pre-mission information was given concerning known position and movement of friendly and enemy forces in the area. Aircrew planned their post RP routes and observation points in pre-mission sessions lasting between 30 – 60 minutes.

Questionnaires. The subjective measurements of situation awareness, workload, and performance were administered at the end of each mission. The comparison questionnaire was administered at the end of the experiment. For each mission, separate questionnaires were completed by the FP and the MC. Participants rated variables on a number of scales (refer to Annex B). In addition, before starting the experiment, participants completed a background questionnaire (see Annex C), which included questions about the number of tactical, Griffon, and simulator flying hours they had logged.

Head Position of MC. Head position data was collected online (30 hz) to determine where the MC was looking throughout each mission. From these data, percent head-up versus head-down time was calculated.

Development of Mission Scenarios. An important activity in this experiment was to further develop the tactical scenarios that were used in E2 of the TAMSS SA project. In particular, the scenarios from E2 were extended to provide a heightened level of activity in the recce zone. Activity included possible fire from the enemy as well as the ability for the Griffon crew to call in a Fire Support from the friendly assets. The scenarios were also evolved to allow for changes in elements such as the location of the FARP. The scenarios also included an enhanced level of radio communications.

Terrain database. The landscape database was a Virtual Reality model of a 40 km (east to west) by 50 km (north to south) section of CFB Gagetown, NB, divided into twenty 10 km by 10 km squares, or "tiles". Due to computer system (memory) constraints, only 6 to 8 tiles (i.e., the minimum required to cover the terrain relevant to a given mission) were displayed during any one mission. The database contained a number of fixed, pre-determined geographical features (river, hills, forest) and man-made elements (barracks, various military installations, roads, and the flight base). Various entities, both moving and stationary, were added to the terrain database to create a number of mission scenarios (see below) in order to assess pilots' situation awareness during missions.

The objects that were placed in the scenarios included:

(a) formation of five M113 armored personnel carriers (mission scenario 1),
(b) one CH-146 Griffon helicopter flying in a circle pattern (scenario 1),
(c) formation of BMP-3 light infantry vehicles (scenario 1),
(d) formation of six M1025 light tactical vehicles (all scenarios),
(e) formation of eight M-109 artillery vehicles (scenarios 1 and 2),
(f) platoon of 6 infantry tents (all scenarios),
(g) formations of M2A3 Bradley Fighting Vehicles (scenarios 1,2 and 4),
(h) formation of six M1A2 battle tanks (scenario 2),
(i) damaged M939A2 5-ton truck (scenario 2),
(j) formation of four BTR-80 armoured personnel carriers (scenario 2),
(k) formation of six M110 artillery vehicles (scenario 3),
(l) crashed Mi-28 attack helicopter (scenario 3),
(m) formation of six M270 self-propelled rocket launchers (scenario 3),
(n) formations of HUM Avenger armoured vehicles (scenarios 1, 3 and 4),
(o) formation of five M1045 TOW missile carrier vehicles,
(p) downed Su-25 ground attack airplane, and
(q) formation of four ZSU-23-4 self-propelled anti-aircraft guns.

The objects were placed so as to be on or near the trajectories or Restricted Operation Zones (ROZ's). Most entities or formations were stationary, but each scenario included at least two formations of moving vehicles (these tended to be vehicle formations that participants had not been briefed on at the outset of their missions). All entities were scaled to their normal size relative to the database.

3.5 Mission Scenarios

Four mission scenarios were used, with terrain features and vehicles as described above. Descriptions of the scenarios are included in Annex A. The missions were roughly equivalent in complexity and number of entities, and all followed a general schema. Participants were first briefed on the general context of the mission, an operation that was designed to resemble United Nations peace support operations that have been put into action on various fronts throughout the Balkans and the Middle East in recent years.

Each mission consisted of a starting point, and intermediate waypoint, a release point (RP), and a Restricted Operations Zone (ROZ) that contained the objective(s) for the mission. The start point, intermediate waypoint, RP were connected by safe flight corridors within which the aircrews were to keep the ownship. The ownship's trajectory within the ROZ was left to the discretion of the pilots.[1]

Each mission began with the ownship airborne at approximately 400 feet above ground level at the start point, and oriented towards the first waypoint. The waypoints were given to the crew on a paper map and were displayed on the ERSTA digital moving map. Participants were instructed to maintain a maximum altitude of 500 feet while transiting from the start/end point and the ROZ, and a maximum of 250 feet in the ROZ (the ROZ was assumed to be capped by active high-speed airspace). In practice, the crew flew at much lower altitudes, especially in the recce zone where tactical flight was maintained.

In each mission, the crew was given the task of locating and assessing the state of a primary objective (generally a bridge or some other strategic landmark). The crew was informed in advance of the entities they were expected to encounter, but each mission included several entities that were not briefed. Also, each mission included unscripted weapons activity (directed either at the ownship or at entities or geographic locations in the terrain) that was controlled on-the-fly by an experimenter using the STAGE software.

3.6 Procedure

Two Mission Specialists (MS) participated in this experiment. One MS participated with the first two pairs of Griffon crew and the second with the last two pairs of Griffon crew. Each MS arrived two days prior to the CH-146 aircrew in order to gain experience operating the ERSTA-like system and to develop procedures related to the functionality and use of the system.

For each pair of pilots, experimentation took place across two days. Upon arrival at the lab on day one, the pilots were provided with information about the general purpose of the experiment and were given an overview of the two-day schedule. The pilots then completed an informed consent and the personal (experience) background questionnaire.

[1] The ROZ was the area within which the actual reconnaissance mission was supposed to take place. The

Following the day one information session, the pilots were introduced to the functionality of the ERSTA-like system that was modeled for this experiment. This introduction was done in combination with the experimenters and the MS (who had two days prior experience in the lab working with the ERSTA-like system). A practice session was then conducted wherein one participant served as the FP and the other participant served as the MC. The practice session was conducted until the FP was comfortable flying tactical with the simulator environment and the MC was familiar with the functionality and use of the ERSTA digital moving map and sensor system (including control of the sensor image). The same practice procedure was completed at the start of day two, except that the CH-146 pilots switched roles.

Each aircrew flew a total of six missions, two missions on day one and four missions on day two. On day one, one pilot served as the FP and the other as the MC for the first two missions. On day two, the roles were reversed for the first two missions. The final two missions on day two were the workload missions which were run with the previous day one assignment of FP and MC roles. These last two missions were designed to obtain an objective measure of the MC's workload.

Each mission took approximately 20-30 minutes to complete. After each mission, the participants were asked to fill out the mission questionnaires. At the end of the second day the participants were asked to fill out a final questionnaire.

The first of each pair of missions was conducted with the MS present. The second of each pair of missions was conducted without a MS.

3.7 Research Personnel

Four experimenters assisted with running the experiment. Experimenter #1 provided online coordination of the scenarios and of the other experimenters. This experimenter monitored the progress of the scenario and decided when radio contacts should be directed to the crew from agents, such as Brigade Headquarters (92) or a Recce Patrol (T43B). Experimenter #1 also

participants were therefore given free reign to set up observation points within the ROZ.

decided when enemy activity would be initiated and when and specifically where the enemy would engage in aggressive action (e.g., fire upon the objective or in the vicinity of the ownship).

Experimenter #2 provided radio contact with the crew by serving at the voice of BDE Headquarters (92), the Recce Patrol (T43B), or friendly artillery (G24), on a need basis in response to contact from the crew and when directed by Experimenter #1. Experimenter #3 controlled specific events in the scenarios using STAGE. Experimenter #4 directed the input of specific data collection information. This experimenter was also responsible for the calibration and monitoring of the head-tracking system and the general status of the simulation.

4 Results

The experimental goals were to extend the evaluation of the Cognitive System Engineering (CSE) framework proposed by the CACR for evaluating the impact of novel technology on aircrew in the CH-146 Griffon helicopter. To do this, the impact of an ERSTA-like system was assessed with a particular focus on how ERSTA affects the performance, situation awareness and workload of the MC. Two conditions were examined: Mission Specialist Present versus No Mission Specialist.

The data from the post-mission questionnaires is listed in Annex E.

4.1 Task-Relevant Performance

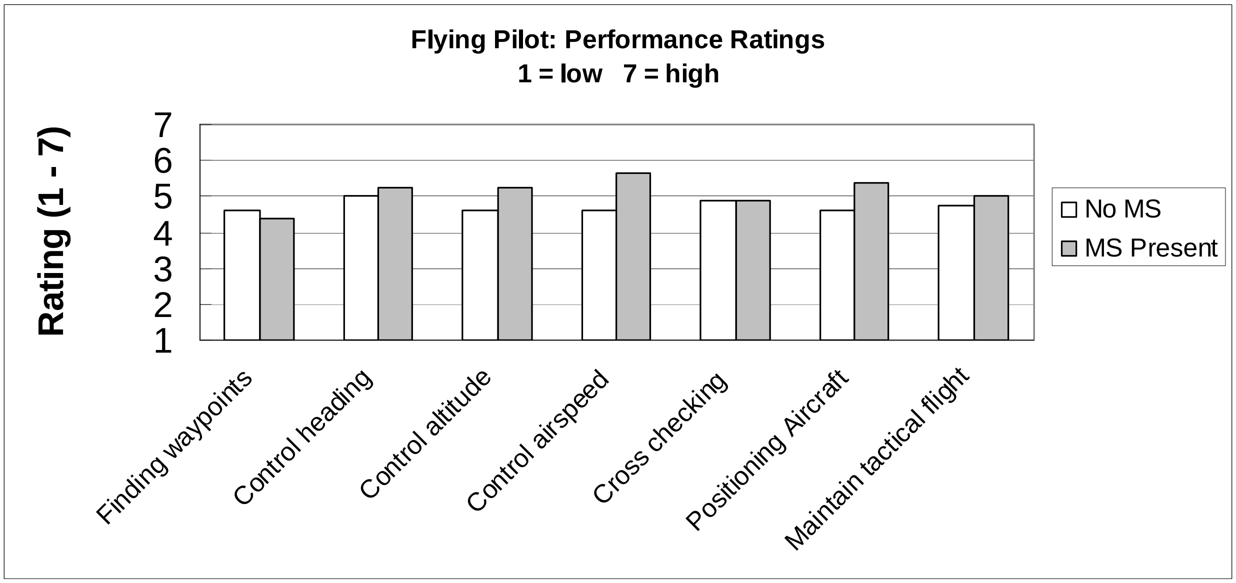
4.1.1 Flying pilot role

Subjective performance ratings. Subjective ratings of performance for the FP role are shown in Figure 4.1. Lower values reflect worse-rated performance where higher values reflect better-rated performance. Overall, FP performance was self-rated as “good”.

In the FP role, participants rated their control of airspeed and, more interestingly, their positioning the aircraft in the recce zone, as being significantly better when a MS was present as compared to when no MS was present.

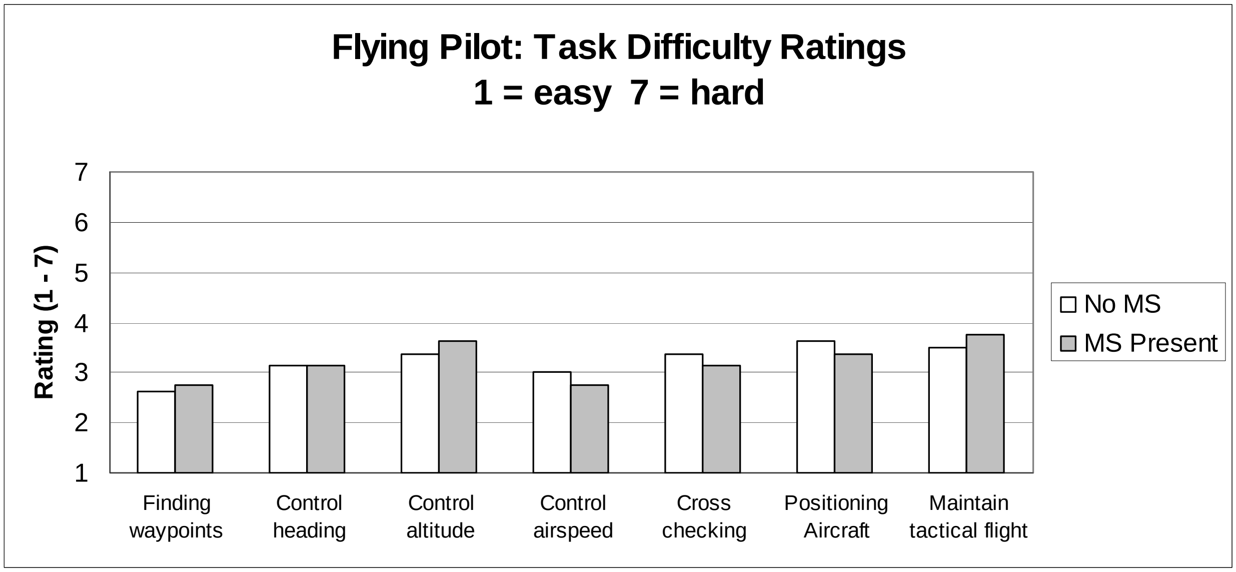
The impact of the MS on positioning the aircraft reflects two factors. First, when a MS was present the MC had more mental resources to allocate toward directing the FP into position. Second, the FP was able to monitor information from the MS and when appropriate position the aircraft accordingly. A typical example was when the MS indicated that the sensor could not be placed on a target or objective because the aircraft was too low. In these cases, the MC would, at their discretion, direct the FP to either provide more altitude or to briefly pop up. During these maneuvers the MS would indicate when the sensor had sight, thereby giving direct feedback that the FP could use to modulate their actions.

Figure 4.1



Subjective difficulty ratings. Figure 4.2 shows subjective ratings of difficulty in performing the same tasks as those assessed in the above performance ratings. Lower values reflect *less* difficulty performing tasks whereas higher values reflect *more* difficulty performing tasks. Overall, difficulty in performing FP tasks was self-rated as slightly less than of moderate difficulty. There were no significant differences in rated difficulty between the MS-present versus the No-MS conditions.

Figure 4.2

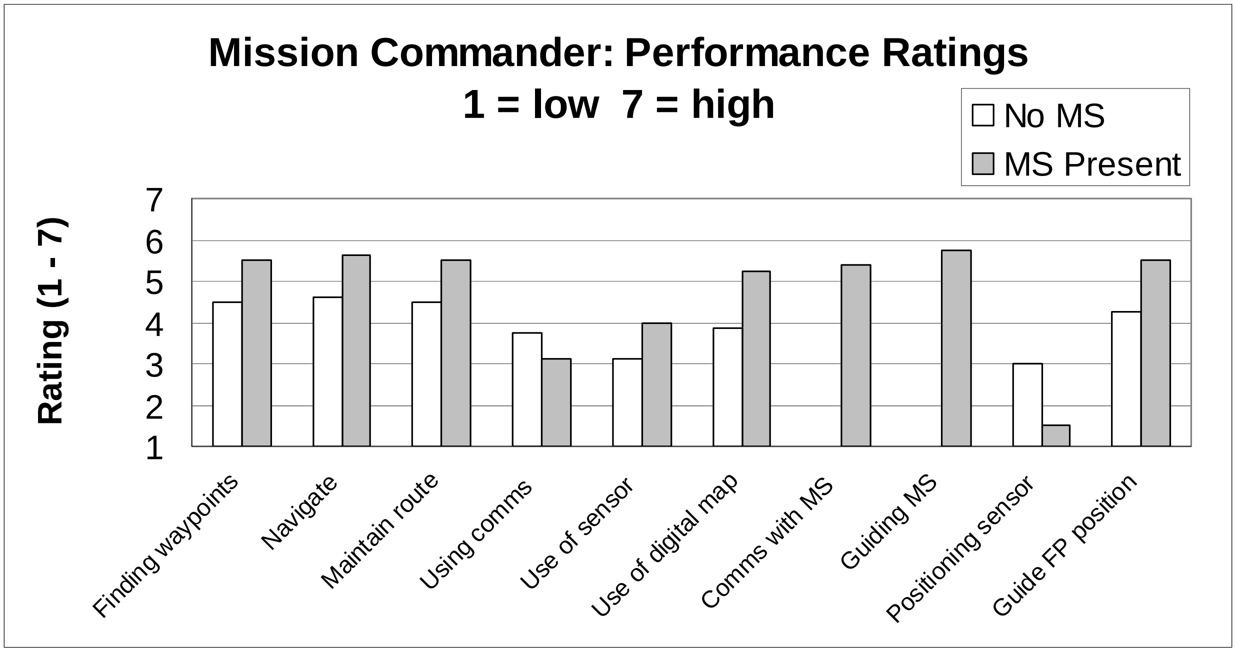


4.1.2 Mission commander role

Subjective performance ratings. Subjective ratings of performance for the MC role are shown in Figure 4.3, first six pairs of bars starting from the left. Lower values reflect worse rated performance where higher values reflect better rated performance.

Self-rated MC performance varied considerably from “slightly less than adequate” to “good”, depending on the task. For the MC role, participants rated their performance on all but two tasks (using comms and positioning the sensor) as being better when a MS was present as compared to when no MS was present.

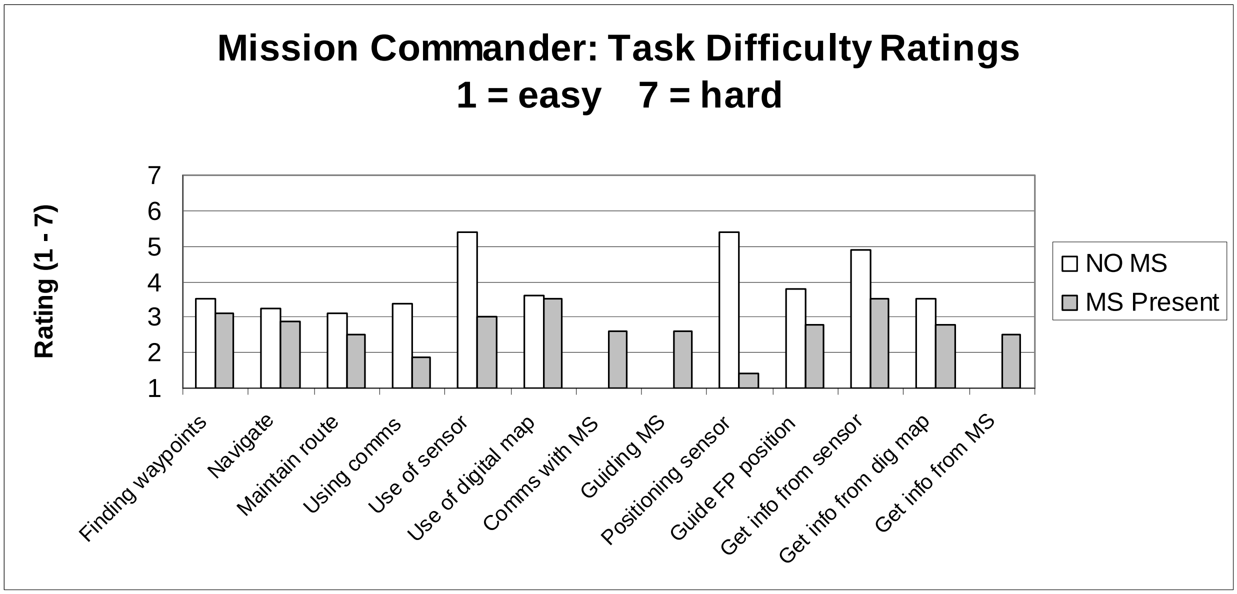
Figure 4.3



Subjective difficulty ratings. Figure 4.4 shows subjective ratings of difficulty in performing the same tasks as those assessed in the above performance ratings. Lower values reflect less difficulty performing tasks whereas higher values reflect more difficulty performing tasks.

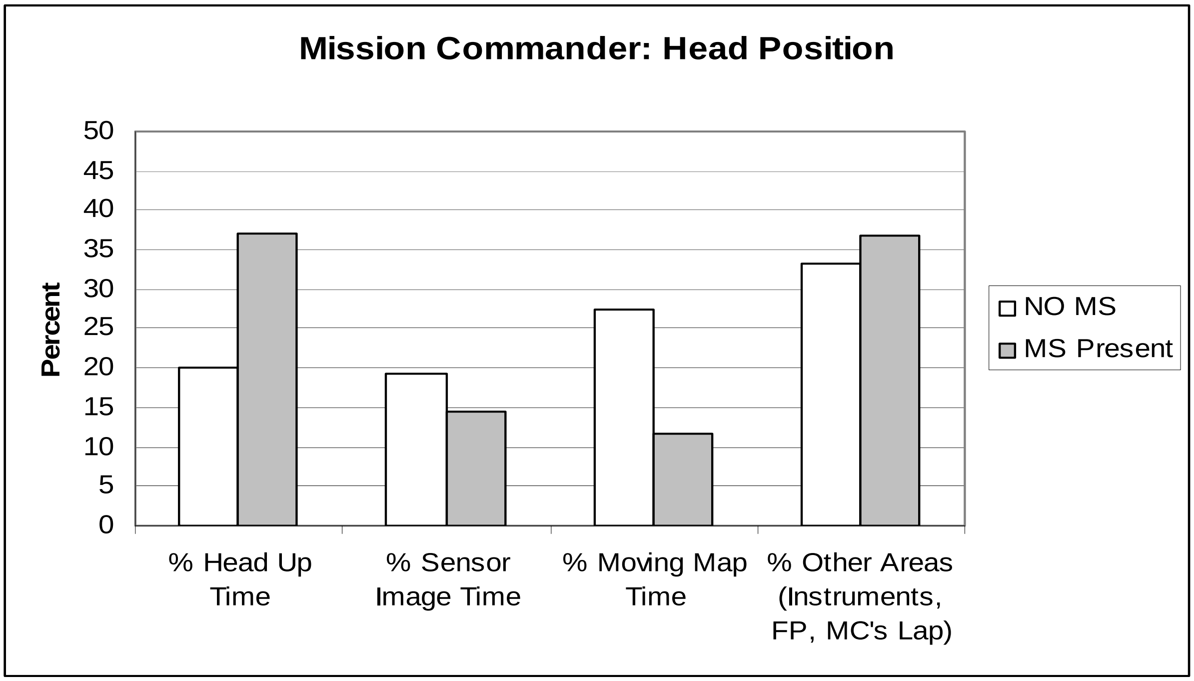
Overall, difficulty in performing the MC tasks was self-rated from "slightly less than moderate difficulty" to "slightly more than moderate difficulty". Overall, task difficulty was rated as higher when in the No-MS condition than in the MS-present condition. As shown in Figure 4.4 large (and all t-tests statistically significant at $p < .05$) self-rated difference in difficulty were found for "using the comms", "use of the sensor capability", "positioning the sensor", "guiding the FP to position the aircraft", and "getting information from the ERSTA system".

Figure 4.4



Objective measure of performance/behaviour: of head-positioning. Head position data for the MC was collected throughout each mission. As shown in Figure 4.5, overall percent head-up time for the MC was significantly greater (better) when a MS was present as compared to when a MS was not present (37.1% vs. 20.1% , respectively, $t(6) = 3.91$, $p < .008$). Head-up time should impact on flight safety and performance: Enhanced head-up time should facilitate the MC's ability to detect and respond to information external to the cockpit. A closer examination of the data in Figure 4.5 shows that when there was no MS present, the MC spent more time (approximately 6%) looking at the sensor image and the digital moving map. This extra time on the sensor was likely due to the additional requirement on the MC to operate the sensor when there was no MS: Operating the sensor requires frequent use of the digital map orienting and moving the sensor (touch-click operation). These findings concurs with the subjective ratings of difficulty where participants indicated that "use of the sensor", "positioning the sensor" and "getting information from the sensor" was quite difficult in the No-MS condition.

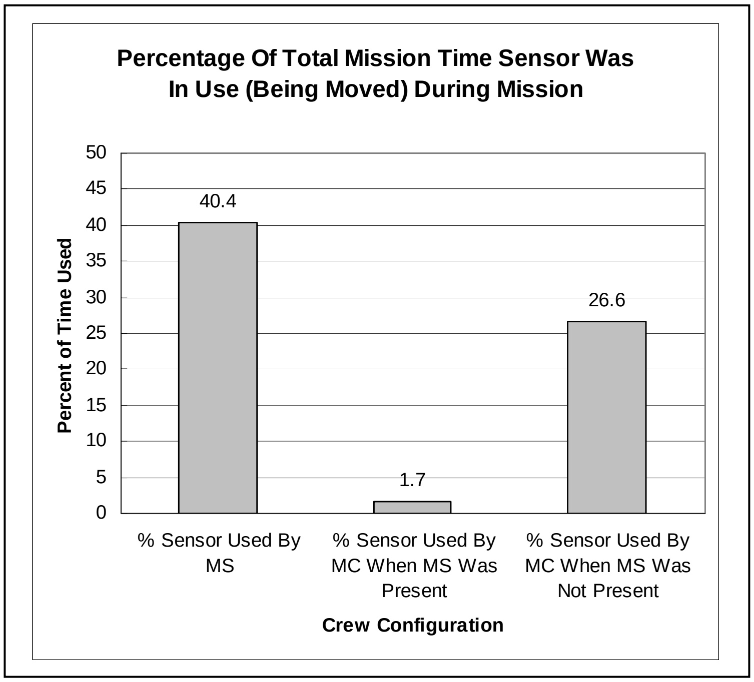
Figure 4.5



Objective measure of performance/behaviour: sensor usage. Figure 4.6 shows the average percent of time that the sensor was used (being moved) relative to the overall mission time. As shown by the far-left data bar, when a MS was present the sensor was moved by the MS for an average of 40.4% of the overall mission time. The middle data bar in Figure 2 shows that, on average, the sensor was being controlled by the MC only 1.7% of the time when a MS was present: thus, the MS had the primary responsibility for moving the sensor.

The far-right data bar in Figure 4.6 shows that when there was no MS present, the sensor was used by the MC for an average of 26.6% of the overall mission time. Thus, when there was no MS, the sensor was used less then half of the time compared to conditions where a MS was included as part of the aircrew. All three of the statistical pairwise comparisons of the sensor usage shown in Figure 4.6 were significant ($p < .05$).

Figure 4.6



4.2 Situation Awareness

4.2.1 Flying pilot role

Subjective ratings of SA. Subjective ratings of SA for the FP role are shown in Figure 4.7 (SA for aircraft system), Figure 4.8 (SA for tactical information, and Figure 4.9 (SA for Spatial Orientation). Figure 4.9 also include ratings for the crew activity. Overall, the FPs rated their SA as “moderate to good”.

In the FP role, only one rating of SA for aircraft systems differed significantly, where the SA ratings were higher in the MS-present than the No-MS condition. This rated SA for “heading” ($t(7) = 2.65$, $p < .034$; Figure 4.7).

A significant difference for Spatial SA and Crew Activity was found for the rated “usefulness of information provided by the ERSTA operator ($t(7) = 3.75$, $p < .008$) (see Figure 4.9). This finding shows that the FPs found the ERSTA-related information to be more useful when the MS was operating the ERSTA system than then the MC was operating the ERSTA system. Related to this is a near-significant difference in rated SA for tactical awareness, and in particular the FP rated ability to anticipate future developments ($t(7) = 2.18$, $p < .065$; Figure 4.8).

Figure 4.7

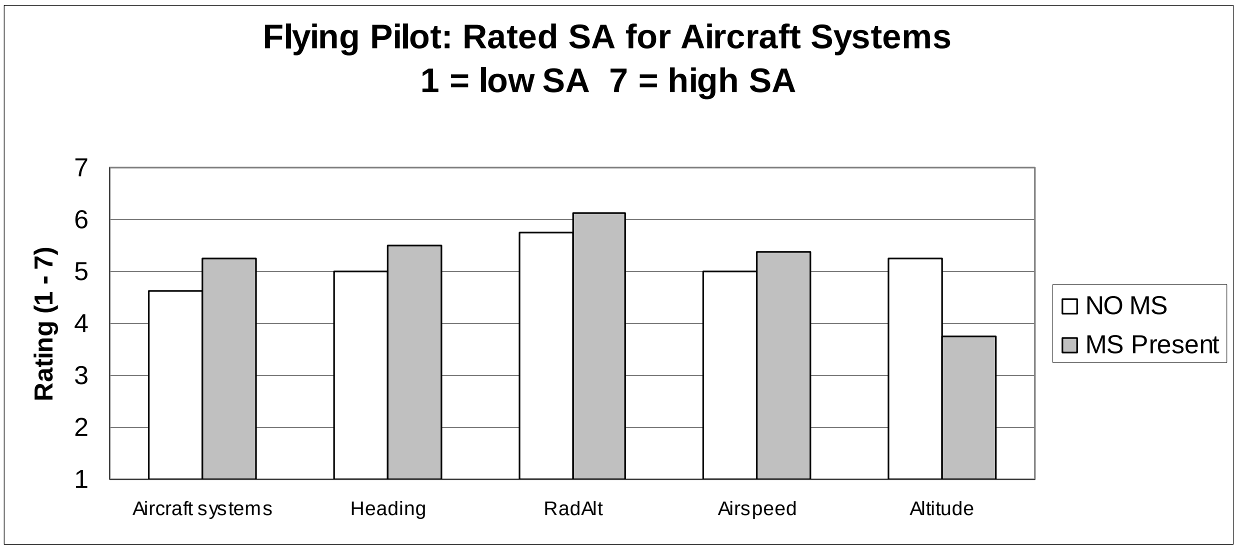


Figure 4.8

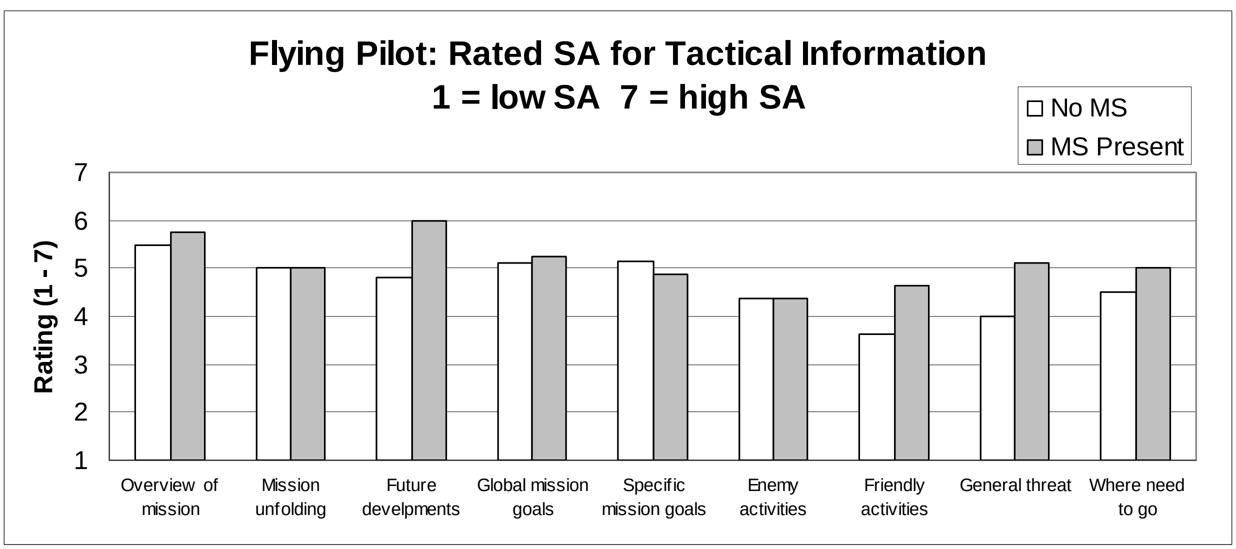
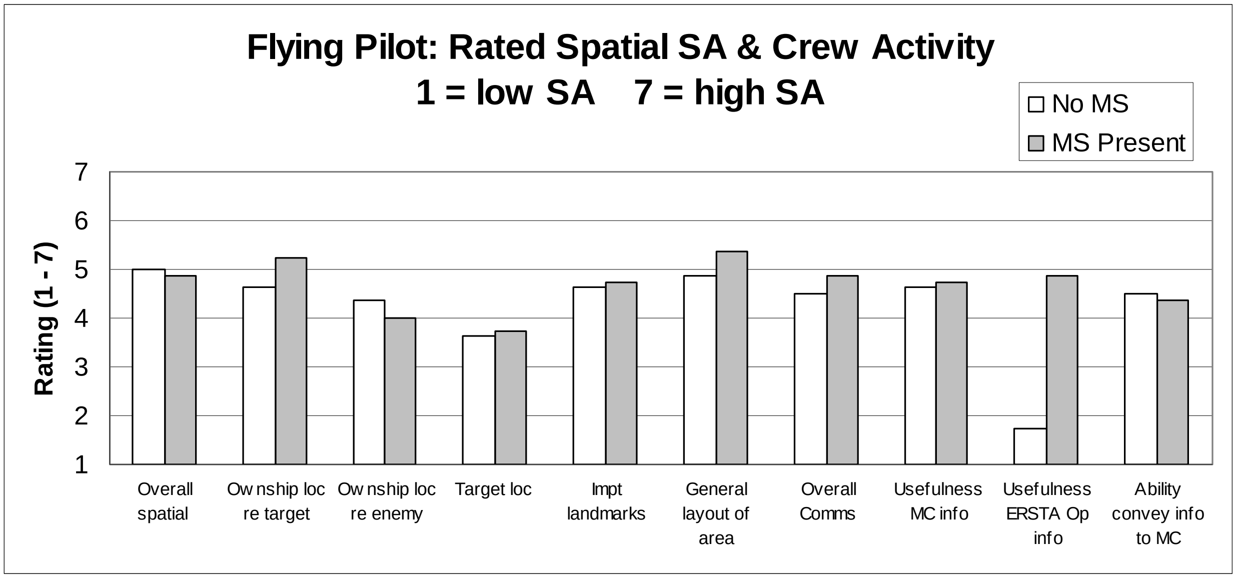


Figure 4.9



4.2.2 Mission commander role

Subjective ratings of SA. Subjective ratings of SA for the MC role are shown in Figures 4.10 (tactical SA), 4.11 (spatial SA) and 4.12 (crew activity SA). Overall, MC SA was self-rated as "moderate to good". For the MC role, SA was generally rated as being significantly higher in the MS-present than in the No-MS condition. This is true for the MCs' ratings of tactical awareness, spatial awareness, and crew awareness.

Figure 4.10

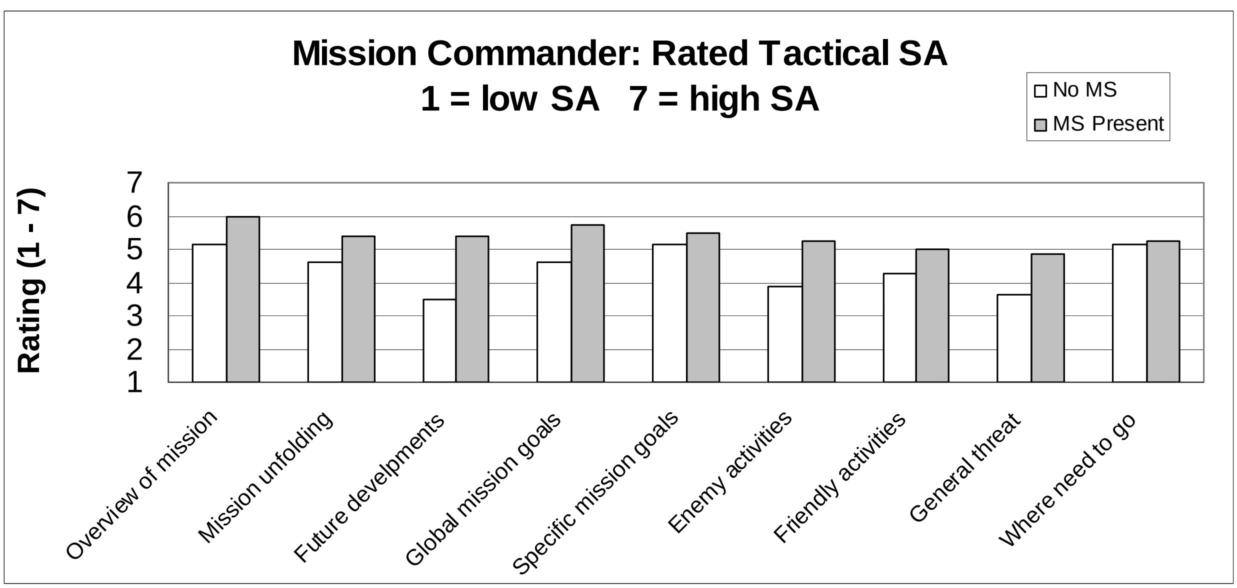


Figure 4.11

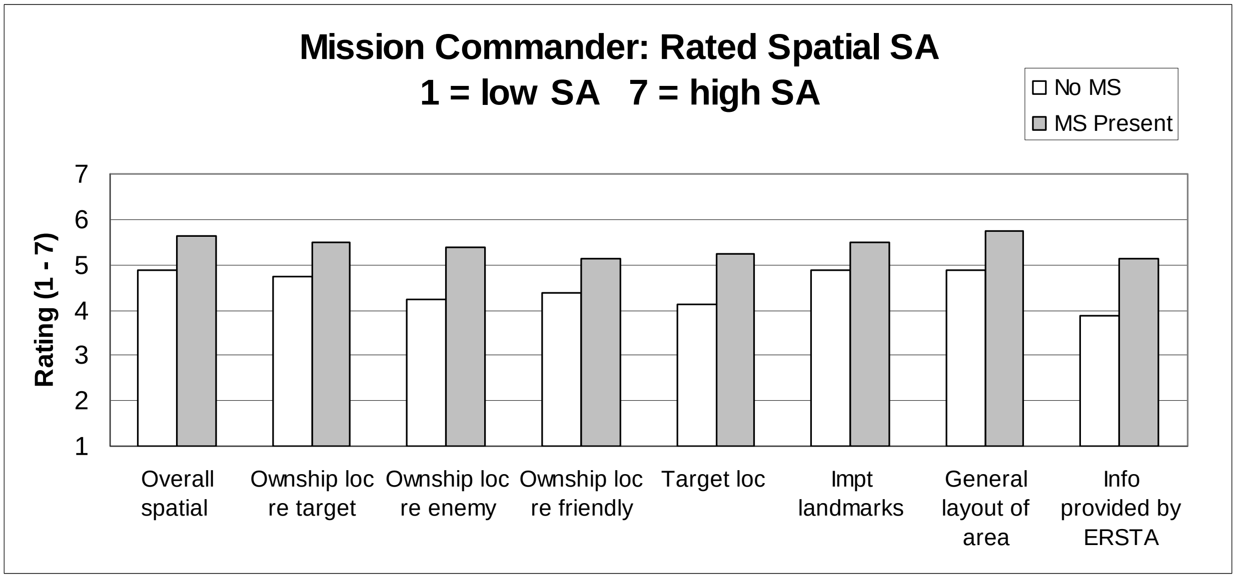
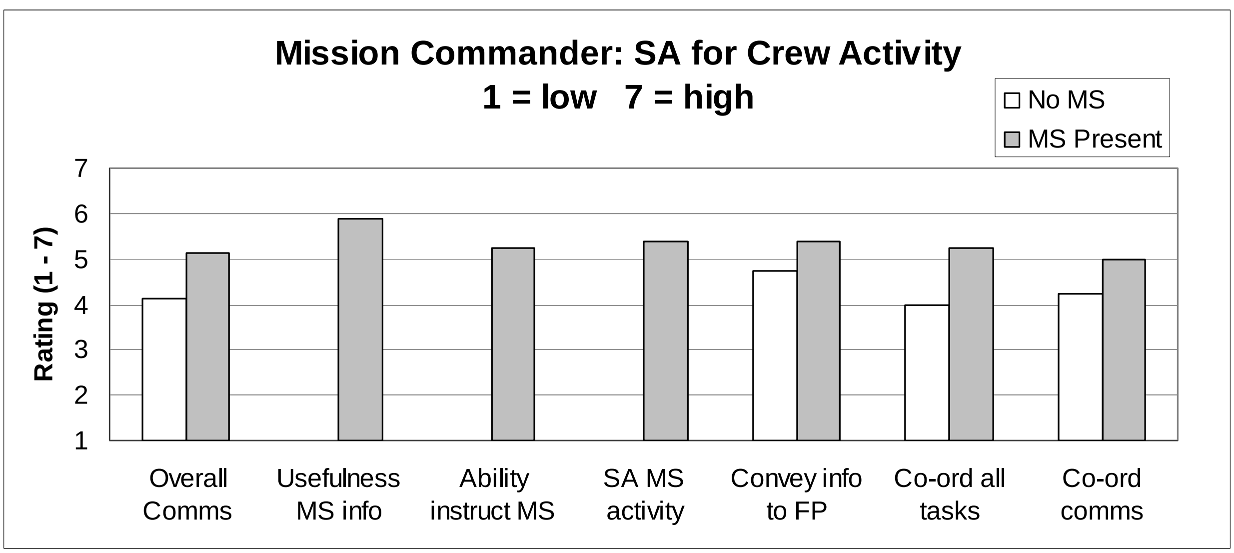


Figure 4.12



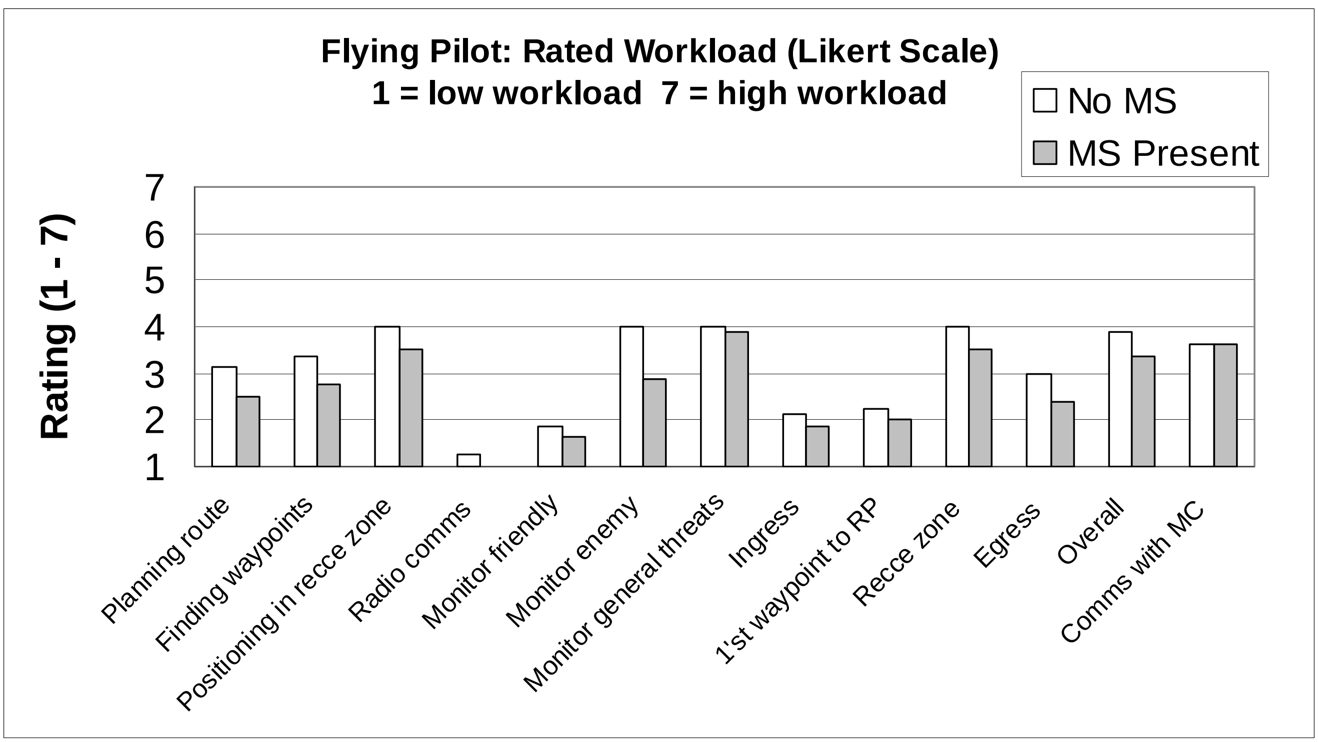
4.3 Workload

The workloads for the FP and the MC were subjectively measured using two scales: a 7-point Likert scale and a modified NASA TLX scale. An objective measure of the MC's workload was also obtained.

4.3.1 Flying pilot role

Subjective ratings of workload: Likert scale. Subjective Likert-scale ratings of SA for the FP role are shown in Figure 4.13. Overall, FP workload was self-rated as "low to moderate". There were no significant differences in self-rated workload between the MS-present and the No-MS conditions.

Figure 4.13

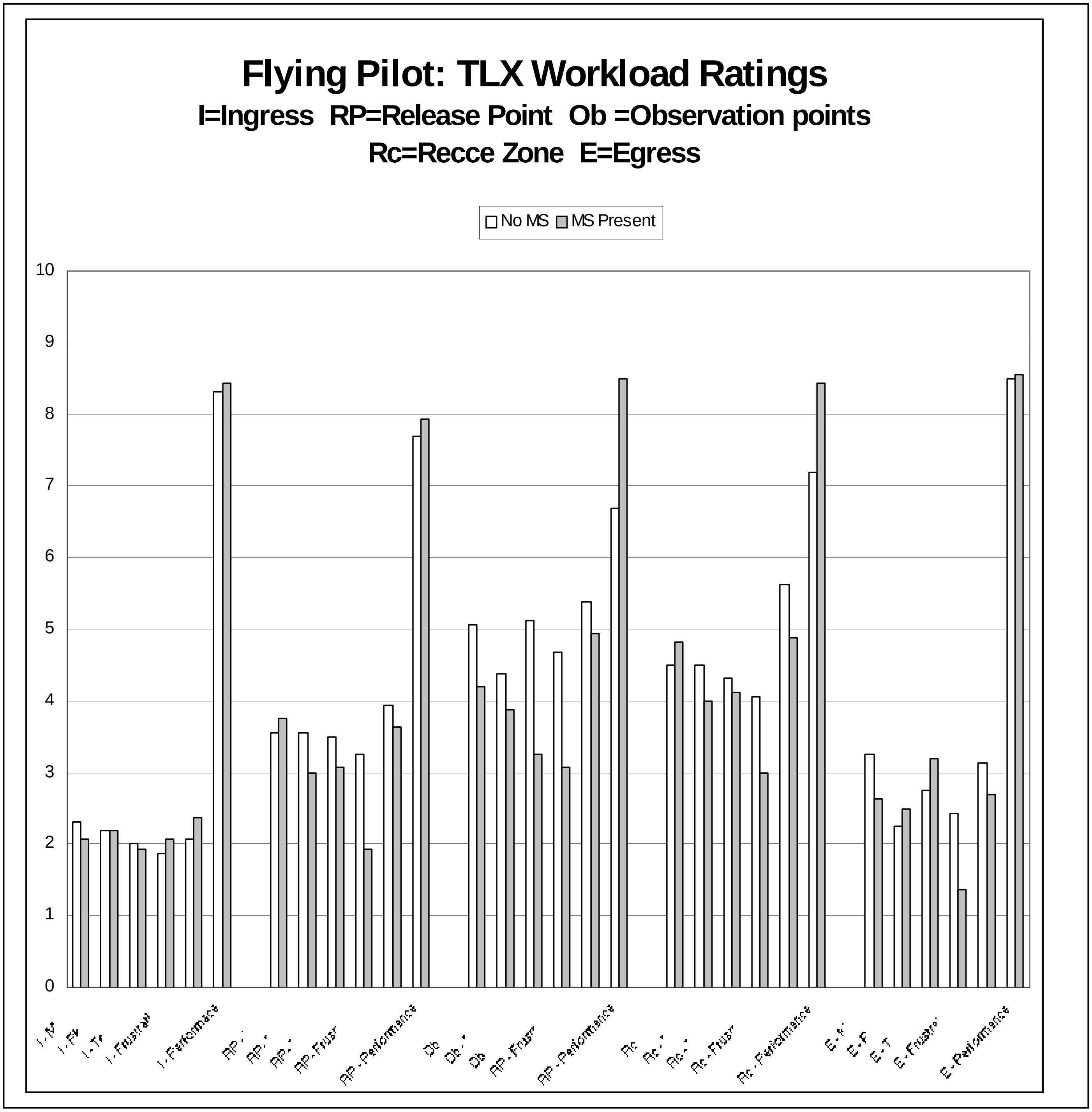


Subjective ratings of workload: NASA TLX. Subjective TLX ratings of SA for the FP role are shown in Figure 4.14. The five quadrants in Figure xx represent TLX ratings associated with the five mission segments: ingress to RP, RP to first observation point, observing a target, activity in the recce zone, and egress.

The pattern of workload for the FP is as expected: overall, workload was rated as lowest during ingress and egress and highest during activity in the recce zone. There was only one comparison for which the FPs' workload was self-rated to be higher in the No-MS than the MS-present condition: temporal demand when getting and maintaining observation (3'rd quadrant in figure) of a target.

The TLX assessment also included one question per mission segment concerning the rated level of performance. These are the spikes in the graph as FP performance was generally rated as quite high. In addition, FP performance was self-rated to be higher in the MS- Present than the No-MS condition for getting and maintaining observation of a target and for level of overall performance activity in the recce zone.

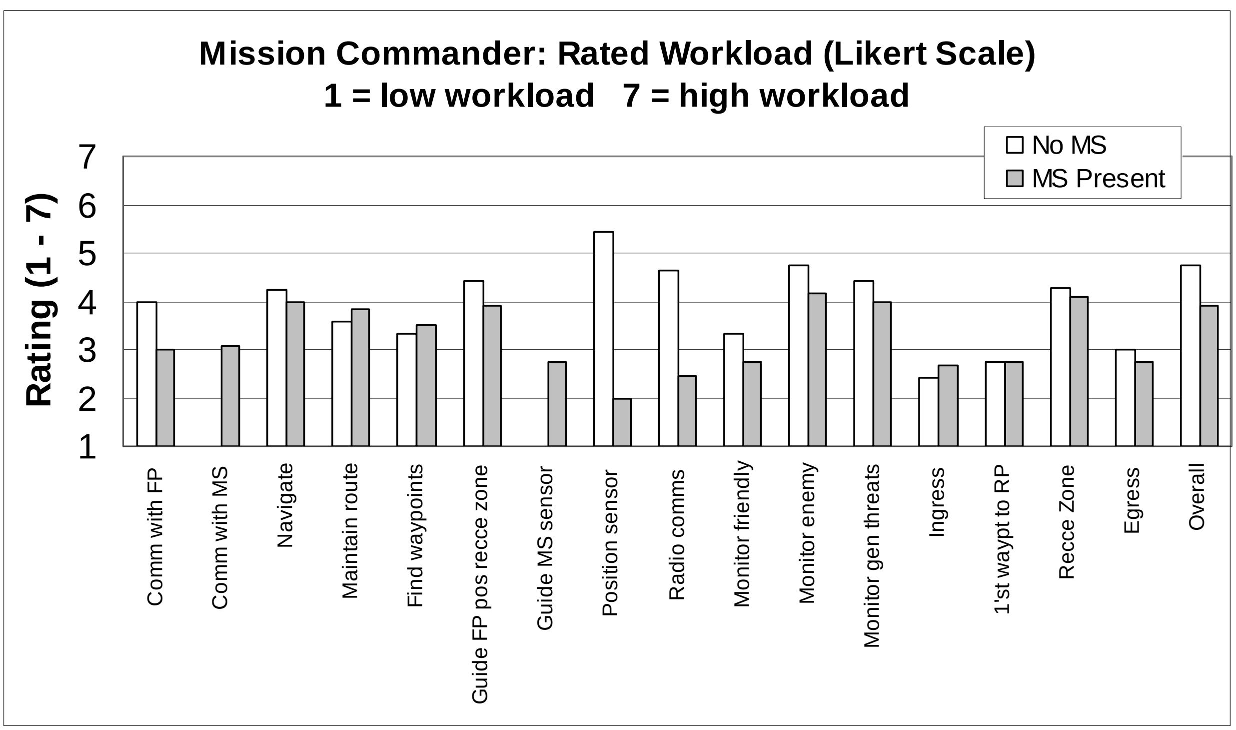
Figure 4.14


Flying Pilot: TLX Workload Ratings
I=Ingress RP=Release Point Ob =Observation points
Rc=Recce Zone E=Egress
No MS
MS Present
10
9
8
7
6
5
4
3
2
1
0
I - Performance
RP - Performance
RP - Frustr
Rc - Frustr
Rc - Performance
E - Performance

4.3.2 Mission commander role

Subjective ratings of workload: Likert scale. Subjective Likert-scale ratings of SA for the MC role are shown in Figure 4.15. Overall, MC FP workload was self-rated as "slightly less than moderate". There were several significant differences in self-rated workload between the MS-present and the No-MS conditions. Of particular note where higher rated workloads in the No-MS condition that were associated with communicating with the FP ($t(11) = 3.63$, $p < .004$) and with the MS ($t(11) = 2.98$, $p < .012$), guiding the MS ($t(11) = 3.23$, $p < .008$), positioning the sensor ($t(10) = 3.15$, $p < .01$), radio communications ($t(10) = 2.67$, $p < .024$), and overall workload ($t(11) = 2.28$, $p < .044$).

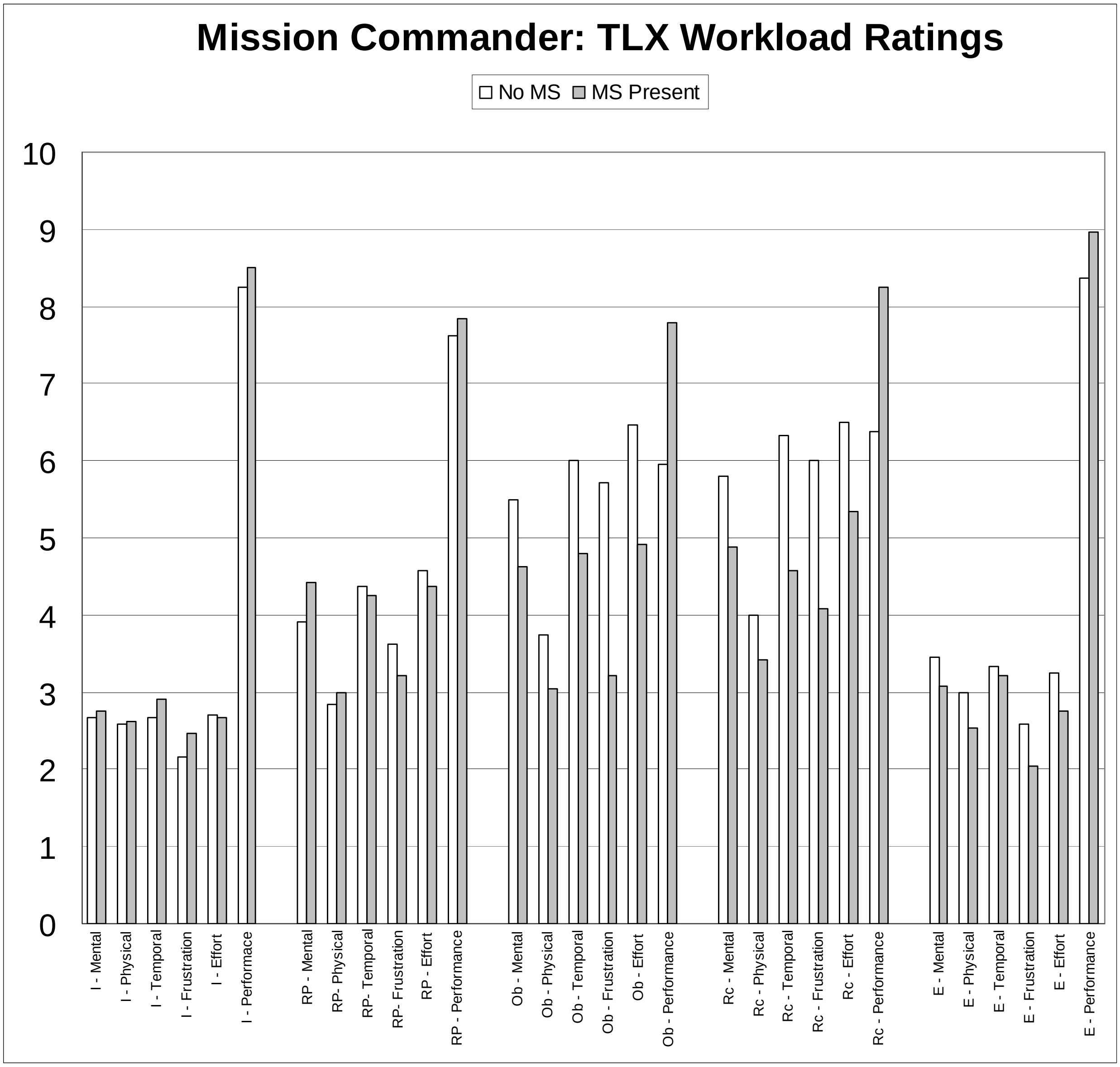
Figure 4.15



Subjective ratings of workload: NASA TLX. Subjective TLX ratings of SA for the MC role are shown in Figure 4.16. The five quadrants in Figure 4.16 represent TLX ratings associated with the five mission segments: ingress to RP, RP to first observation point, observing a target, activity in the recce zone, and egress. The pattern of workload for the MC is as expected: workload was rated as lowest during ingress and egress and highest during activity associated with observing targets and activity in the recce zone.

As shown in Figure 4.16, for the ingress , RP to observation, and egress segments, there were no significant differences in rated TLX workload between the No-MS versus the MS-Present conditions. In the observation segment, self-ratings were higher in the No-MS than the MS-present condition for frustration ($t(11) = 4.25$, $p < .001$), effort ($t(11) = 2.43$, $p < .034$) and performance ($t(11) = 4.53$, $p < .001$). In the recce zone segment, self-ratings were higher in the No-MS than the MS-present condition for temporal demand ($t(11) = 2.65$, $p < .023$), frustration ($t(11) = 2.47$, $p < .031$), effort ($t(11) = 2.05$, $p < .06$), and performance ($t(11) = 3.47$, $p < .005$).

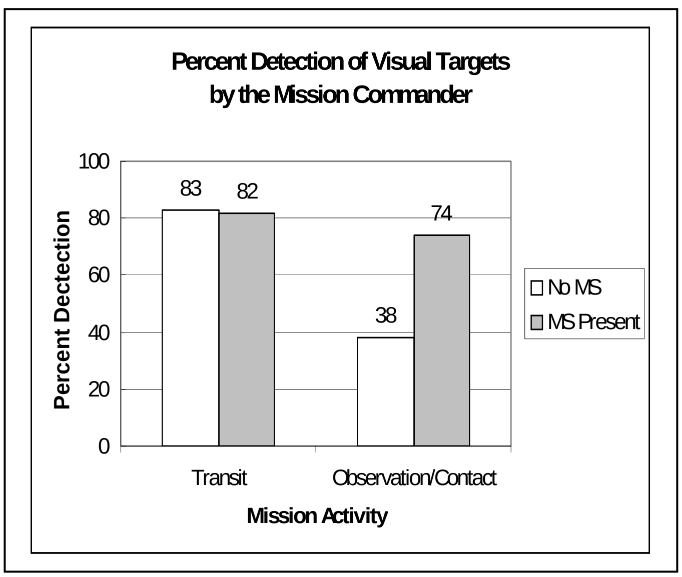
Figure 4.16



Objective measure of workload. The MCs' workload was objectively assessed using a visual detection task whereby the MC was required to indicate when they detected a visual target (a briefly displayed green circle) on the front screen. The targets subtended approximately 2 deg of visual angle and were presented every 15 sec (+/- 3 sec randomly determined) throughout the workload missions. The MC was required to push a foot switch whenever they detected a visual target. The measure of performance was percent visual targets that were detected.

The MC responses to the visual targets was divided into two classes of activity: transit versus observation. The transit category includes the MC responses to the visual targets when the crew was engaged in the initial ingress, transit from the RP to the first observation point, moving from one observation point to another observation point, and egress. The observation/contact category refers to MC responses to the visual targets when the crew was observing a target/objective, submitting a contact report, or performing a FSM. As shown in Figure 4.17, MCs detected most (average of 82%) of the visual targets while in transit. Performance while in transit did not differ between the MS-Present versus the No-MS conditions. In contrast, the MCs detected fewer visual targets (average of 56%) while in an observation/contact phase. Moreover, there was a difference across conditions where significantly fewer visual targets were detected in the No-MS than in the MS-Present condition. This result shows that the MC had less visual attention to allocate to the target detection task in the No-MS condition than in the MS-Present condition.

Figure 4.17



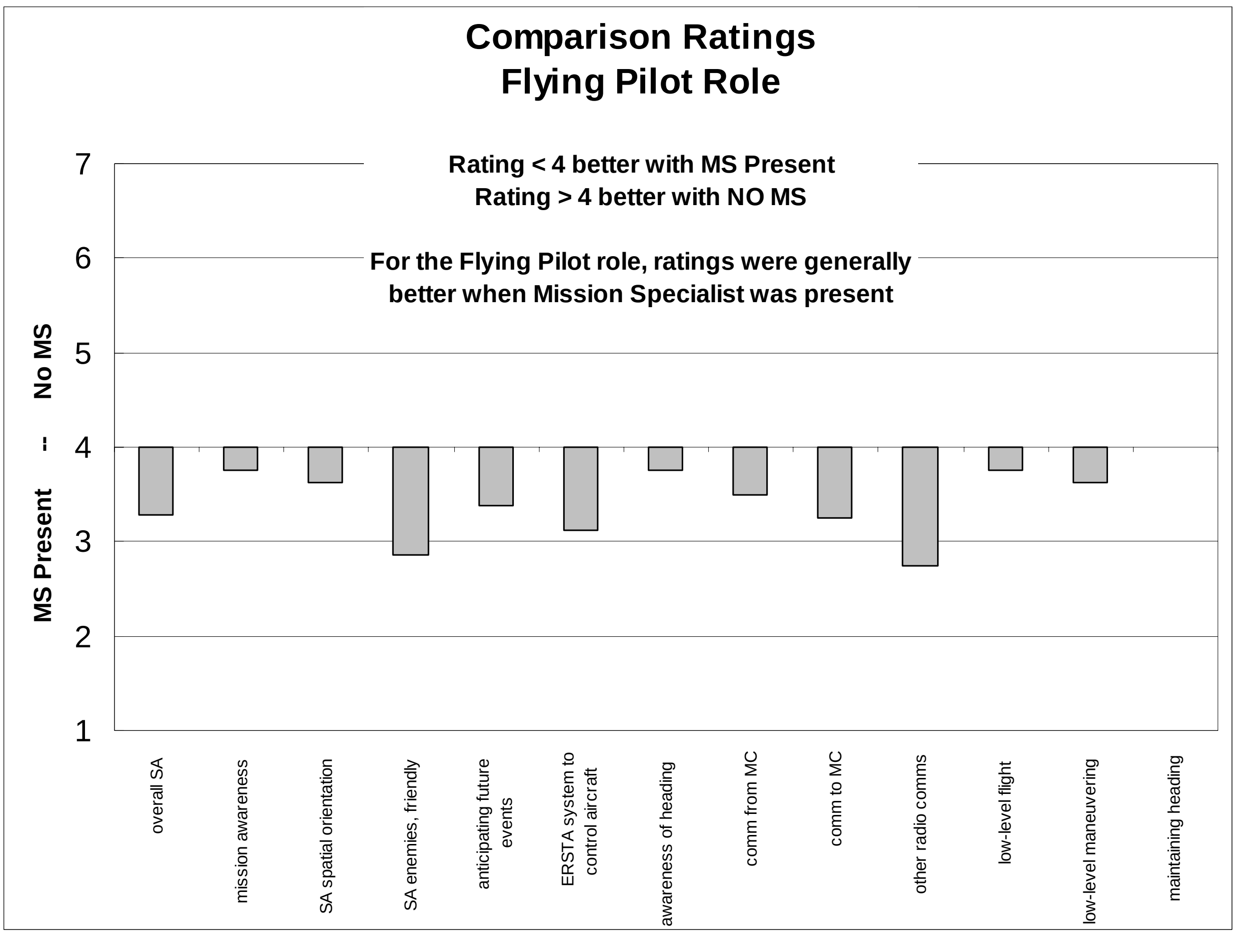
4.4 Post-mission comparison ratings

At the end of the each day of testing, participants completed a questionnaire to directly compare the MS-Present versus the No-MS conditions for both the FP and for the MC roles. The post-mission comparison questionnaire is shown in Annex F and the corresponding average ratings are shown in Annex G.

4.4.1 Flying pilot role

Figure 4.18 summarizes the comparison ratings for the FP role. In this Figure, a value of "4" would indicate that there is no rated difference between having a MS present versus having no MS. As seen in Figure 4.18, all of the comparison values are slightly less than 4. This shows that for the FP role, participants rated their performances and experience as a MC as slightly better when a MS was present as compared to when no MS was present.

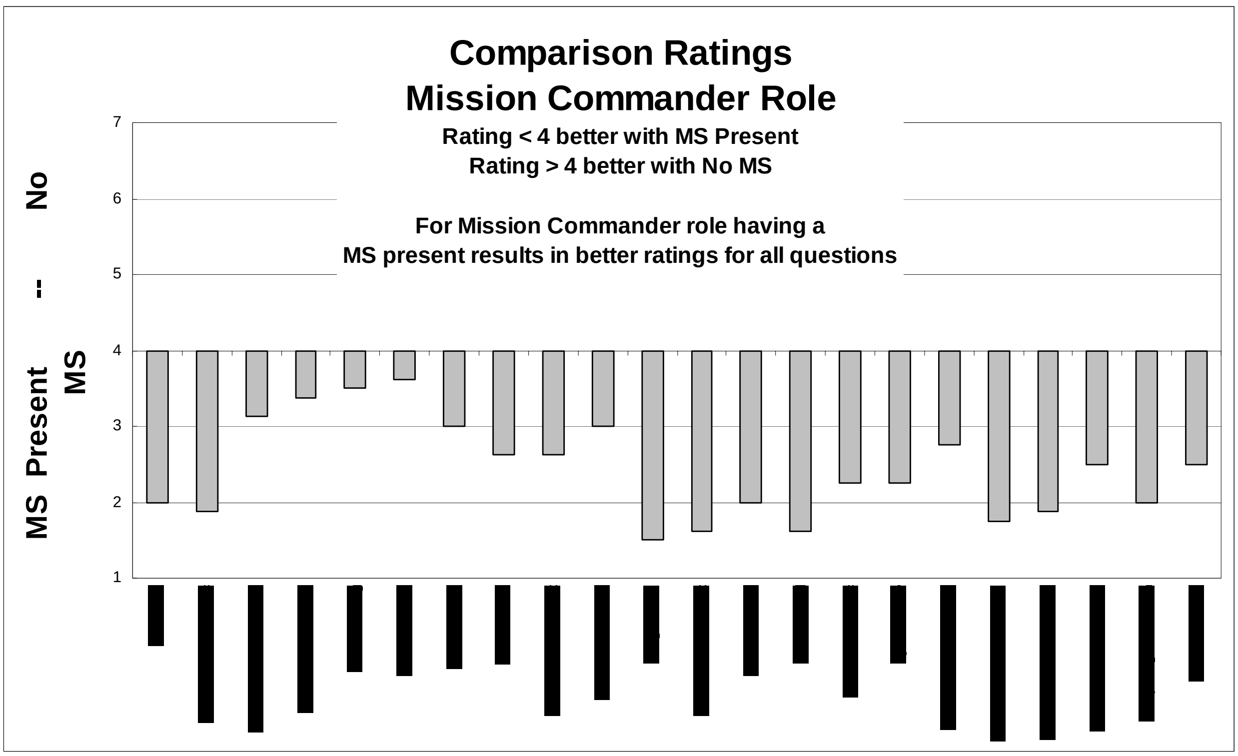
Figure 4.18



4.4.2 Mission commander role

Figure 4.19 summarizes the comparison ratings for the MC role. A value of “4” would indicate that there is no rated difference between having a MS present versus having no MS. All of the comparison values are less than 4 with many reaching a value of 2 or less. This shows that for the MC role, participants rated their performances and experience as an MC as better when a MS was present as compared to when no MS was present.

Figure 4.19



5 Conclusions

In this experiment, the CSE framework developed at the beginning of the TAMSS SA project was used to examine the question of how the presence of a mission specialist would affect the situation awareness, performance, and workload of the CH-146 aircrew during recce missions. The advantage of using the CSE framework is that it provided a comprehensive set of measures that allowed a broad overview of how the mission specialist affected the task. Furthermore, the use of both subjective and objective measures of SA, workload, and performance allowed confirmation across the various aspects of the situation.

When participants took the role of the flying pilot, the presence of the mission specialist had a moderate effect on performance. Subjectively, the FPs felt that their performance was somewhat better when a mission specialist was present, particularly in the observation and recce phases of the mission. There was little evidence for an influence of the mission specialist on situation awareness or workload for the FPs. Because the focus in this experiment was on the mission commander, no objective measures of performance were collected.

When participants took the role of the mission commander, they reported substantial effects on performance, workload, and SA. In general, the MC found it easier to interact with the ERSTA system when a mission specialist was present. The reduced workload generalized to using the radio comms suggesting that the MC felt generally overloaded when the task of operating the sensor was added to all of the other demands of the missions. As in the FP role, the MCs felt that their workload was increased in the observation and recce phases of the missions. The results of the objective measurements supported the subjective results. In the presence of the mission specialist, the MC showed a greater amount of heads-up time, looked at the sensor image less, and the sensor itself was moved less. Objective workload was also greater for the MC when he or she was operating the sensor. Substantially fewer targets were detected, especially in the portions of the mission (observations and in contacts in recce zone) that required the MC to be processing other information or interacting with other aspects of the technology.

In summary, these results provide a clear picture of how the presence of a mission specialist enhanced the subjective and objective task performance. The mission commander, freed from the increased demands of operating the sensor, had more mental attention to put towards the primary demands of the MC role.

Experiment 3 was also technically progressive. The ERTA-like model was successfully extended to provide the requisite level of functionality thereby enabling the aircrew to use the digital moving map and the sensor capabilities in a realistic and appropriate manner. The simulation environment was robust and stable. The data collection utility was stable and accurate throughout the experiment and the HLA-based distributed simulation which the CACR used to connect the model of the ERSTA system to the CACR CH146 flight simulator ran flawlessly for a minimum of eight-to-ten hours per day across twelve days of testing.

The finding that the impact of cockpit technologies (e.g., digital map, sensor) on crew performance, situation awareness, and workload can be systematically measured allows for three important conclusions. First, it is concluded that the CSE framework is a useful and workable framework for M&S programs. Second, it is concluded that the impact of new aircraft technologies on aircrew can be systematically and meaningfully measured using the level of system fidelity that is represented in the CACR simulation environment. Third, it is concluded that the CSE framework and the simulation environment that was developed in the TAMSS SA project can be used to affect the design, prototype, test, build and implementation processes in simulation-based acquisition programs.

ANNEX A

Mission Scenarios

TI-02 TAMSS SA – EXPERIMENT #3 – ZONE RECCE #1

Tactical Scenario - Peace Support Operations

It is day 10 of Op NOMAD. Op NOMAD is the UN counteroffensive to push the final elements of the FDN troops out of the territory formerly known as Gagetownia. The FDN troops have been invading this territory for the past 14 months, conducting sporadic attacks on innocent civilians in an attempt to drive them out of the territory. Recently, in the past four months, the attacks have increased in number and in ferocity.

A number of emergency UN meetings have occurred resulting in a UN Chapter 6 operation (Op NOMAD) with the main objective to force the FDN troops out of the territory and allow the local Gagetownians to live in peace.

The FDN are a well equipped para-military organization who have been trained by Soviet forces, having been occupied as a soviet state for many years. Their equipment is predominantly Soviet based.

Future MNB operations require a number of critical areas to be maintained intact for the UN troops to continue the push to the St John River. These key areas are the bridges crossing the Oromocto, Nerepis and Otnabog Rivers and choke points out of the hilled areas on the West side of the St John river leading to the main river crossing areas used by the FDN for their initial invasion some 14 months ago.

The UN force is being led by the UN Multi-National Brigade (UNMNB) under the command of BGen Stolitchnoya (callsign Stiletto) from Lithuania. The main UN offensive has pushed the main FDN forces out of the territory. However, it is expected that a number of layback patrols have remained in the area to disrupt the UN operation and slow down the advance. This will allow time for the FDN forces to regroup and attempt to re-start their guerrilla activities.

Canada has provided the following forces:

- a Mech Inf Coy (A Coy 2PPCLI) attached to a UK Inf Bn
- a Recce Tp (A Tp LdSH) attached to a GE armoured unit
- a helicopter Flt (B Flt 408 Sqn) assigned to MNB HQ
- fighter assets from 4 Wing Cold Lake

Other UN assets of importance include:

- Arty (M109) and Armd (Leo 2) from the German 5 Spa-Panzer Div (SPD)
- UK Inf Bn (3 Bn Royal Grenadiers)
- US Inf Bn (2 Bn 1 ID)
- AWACs support
- CAS (GR8s) from RAF Wittering, deployed to an undisclosed 5 ATAF field location
- CAS / CAP support (CF18s) from 4 Wing, deployed to an undisclosed 5 ATAF DOB

Currently, the helicopter unit is located some 45 km West of the objective area, at the Brockway Airfield (FL 480485).

The MNB has secured (albeit loosely) a number key areas, important to the Op NOMAD advance. These include:

- bridges at:

	Bridge Name
GL 105558	100
GL 097533	101
GL 091499	102
GL 063467	103
GL 098450	104

- choke points at:

	Choke Point Name
GL 187647	200
GL 205578	201
GL 190468	202
GL 211431	203

You are a Griffon crew assigned to conduct Recce tasks with the newly equipped ERSTA system. The Comd UNMNB has been impressed with the support provided to date since the ERSTA is the best long range rapidly deployable Recce system available in the Bde. The ERSTA equipped Griffons played a key roll in aiding the rapid advance of the MNB in the past 9 days.

It is 0830 and you have been informed that you are required to complete a mission of significant importance. The mission needs to be done quickly since the momentum of the MNB push through the territory may be halted as a result of possible FDN activity.

The HQ has lost contact with a patrol securing the bridge at GL 091499. The last report from the patrol indicated that they had been fired at sporadically from the surrounding hills to the East of their positions. It is extremely important that the HQ determine the status of the bridge and if the FDN are attempting to mine or destroy the bridge.

Pre Flt Brief to Crew from Ops

Situation:

General:

- as per intro

En:

- likely en activity in area of GL 091499 (objective) (last contact by patrol in area)
- contract report - sniper activity in area GL 1856 - 6 hrs ago
- intsum - bypassed en units (Platoon -) East of 20 Easting
- contact report - en patrol raided village in area of GL 0449 - 12 hrs ago, appeared to be headed East

Fr:

- Recce Tp located in area GL 0555 (6 x HUM TOW)
- Arty Bty located at FL 998504 (8 x M109-A6)
- Inf located at GL 059531 (camouflaged tents)
- Patrol on bridge at GL 082519 (3 x HUM AVENGER + 1 x M2A3 BRADLEY)
- attached for duration of mission - W Bty through G24
- CAS on call from MAGIC (10 min. notice required)

Wx:

- 5000 OVC, 4 NM vis, localized drizzle, temp 15°, dewpoint 10°, pressure 29.95"
- sunrise: 1200Z, sunset: 0300Z

Airspace:

- restrictions as per ACO

Mission:

Gain observation on the bridge at GL 091499 to determine if the bridge is intact and observe the bridge until T43B elements arrive.

Execution:

General Outline:

- In line with the mission, you have three objectives:

    1. gain observation onto the bridge
    2. determine if the bridge is intact
    3. maintain observation until T43B arrives

Groupings and Tasks:

- You will be the sole CH146 equipped with ERSTA on the mission

Fire Support:

- arty is available on call throughout the mission through G24
- CAS is available through MAGIC on 10 min notice

AD Assets:

- 1 x M2A3 BRADLEY is located at GL 141579 (5 km Radius down to 50')

Co-ord Inst:

- timings: depart on mission NLT 0930
- route: as per ACO
- upon passing RP contact Bde HQ (C/S 92) and advise of ETA on observation area
- maintain contact with 92 through-out Recce phase

Service Support:

- FARP at GL 027481 (open 1000-1030) - fuel only (HEMTT Fuel Bowser)
- FSH located at FL 884566
- pers eqpt - SOP

Command and Signals:

Command:

- UC 408 Sqn B Flt
- TACCON Bde HQ (C/S 92)

Codewords:

- objective under observation SPYGLASS
- objective intact MANHOLE
- objective destroyed COLDSTART

COMMs:

- as per CEOIs

Airspace Control Orders

A special helicopter corridor has been reserved for this mission:

	Co-ord Point	Location	Altitude	Time (Z)
Ingress	TWEED	FL 560565	< 500'	0930 -1000
	BLISSVILLE	FL 912532		
	FINNEGANS	FL 995577		
RP	CLONES	GL 057552	< 250'	N/A
Egress	PETERSVILLE	GL 046498	< 500'	1000 -1100
	BLISSVILLE	FL 912532		
	TWEED	FL 560565		

The area in the vicinity of the objectives has been co-ordinated with MNB HQ to be restricted from other friendly helicopter activity except for emergency operations and enemy contact. The Restricted Operations Zone (ROZ) is capped at 250' and is bounded by:

- GL 106442
- GL 077450
- GL 095575
- GL 131563

There is an active LLTR immediately South of the objective bridge, passing immediately above the ROZ (250'-500'), one way, headed SW. It is expected that some friendly fighter activity may be using the LLTR on egress from BAI missions in FDN held territory East of the St John River. The LLTR is aligned with:

- GL 2756 and FL 9039

All aircraft activity in the territory is co-ordinated with AWAC (Magic). Upon passing any co-ord point or release point a call is to be made indicating your callsign and the point you passing.

PL FIR

FL 850550, FL 960613, GL 040633, FL 222655

PL OAK

FL 850440, GL 046498, GL 256575

PL ASH

FL 850330, GL 078371, GL 269496

PL BASS

FL 956690, FL 910623, FL 897580, FL 924465, FL 992405, FL 960330

PL DOG

FL 965686, FL 967640, GL 006553, GL 070435, GL 087412, GL 079369, GL 117338

PL HORSE

GL 000720, GL 037662, GL 059588, GL 124550, GL 114522, GL 172502, GL 247389

Communications Electronic Operating Instructions:

COMMs:

Unit	C/S	Freq	Crypto
AWAC	MAGIC	HQII / A19.225	No
Bde HQ	92	34.50	Fill 5
Patrol	I23A	33.90	Fill 4
Arty	G24	35.20	Fill 3
Recce Tp	T43B	42.65	Fill 1
Flt Ops	0	49.90	Fill 2
FARP	52C	46.50	Fill 2
CAS (on call)	KUGAR	HQII / A03.625	No

IFF:

IFF Mode	Time	Code
Mode 1:	0900-0930	02
	0930-1000	73
	1000-1030	61
	1030-1100	51
	1100-1130	40
	1130-1200	22
Mode 2:	N/A	1324
Mode 3:	1200	
Mode 4:	0000z-1200z	A
	1200z-2400z	B

Experimenter Inputs:

The sortie will commence with the Griffon safely airborne at the 2nd pre-planned Co-ordination Point, at an altitude of 400 feet AGL, on track and heading to the next Co-ordination Point. Once the aircrew is comfortable the simulation will be uncaged; the time will be 0945Z.

Experimenter Inputs (NOT FOR EXPERT USER CONSUMPTION):

These activities are **NOT** briefed to the crew – in order to allow the aircrew to interact with the dynamic of the synthetic environment and react accordingly.

The following dynamic events will be programmed to occur during the "sortie":

- 5 x M113 APCs will transit NW on the black track from GL 050553 to GL 023569. The APCs need to be moving as the helicopter is transiting between FINNEGAN and CLONES.
- A burning/crashed AH-64 Apache will be on the ground at GL 070554.
- 4 x BMP Armoured Fighting Vehicles will transit North on the road from GL 092470 to GL 114522. The BMPs need to be moving as the Griffon reaches CLONES.

TAMSS SA – EXPERIMENT #3 – ZONE RECCE #2

Tactical Scenario - Peace Support Operations

It is day 10 of Op NOMAD. Op NOMAD is the UN counteroffensive to push the final elements of the FDN troops out of the territory formerly known as Gagetownia. The FDN troops have been invading this territory for the past 12 months, conducting sporadic attacks on innocent civilians in an attempt to drive them out of the territory. Recently, in the past three months, the attacks have increased in number and in ferocity.

A number of emergency UN meetings have occurred resulting in a UN Chapter 6 operation (Op NOMAD) with the main objective to force the FDN troops out of the territory and allow the local Gagetownians to live in peace.

The FDN are a well equipped para-military organization who have been trained by Soviet forces, having been occupied as a soviet state for many years. Their equipment is predominantly Soviet based.

Future MNB operations require a number of critical areas to be maintained intact for the UN troops to continue the push to the South and West of the St John River. These key areas are the bridges crossing the Nerepis River and choke points along the road paralleling the NW-SE rail line and extending South to the St. John River. Wellsford was a main crossing area used by the FDN during their initial incursion some 12 months ago.

The UN force is being led by the UN Multi-National Brigade (UNMNB) under the command of BGen Ruberg (callsign Thunder) from Lithuania. The main UN offensive has pushed the main FDN forces out of the territory. However, it is expected that a number of layback patrols have remained in the area to disrupt the UN operation and slow down the advance. This will allow time for the FDN forces to regroup and attempt to re-start their guerrilla activities.

Canada has provided the following forces:

- a Mech Inf Coy (A Coy 2PPCLI) attached to a UK Inf Bn
- a Recce Tp (A Tp LdSH) attached to a US armoured unit
- a helicopter Flt (B Flt 408 Sqn) assigned to MNB HQ
- fighter assets from 4 Wing Cold Lake

Other UN assets of importance include:

- Arty (M109) and Armd (ABRAMS) from the 1st US Armd Div
- UK Inf Bn (3 Bn Royal Grenadiers)
- US Inf Bn (2 Bn 1 ID)
- AWAC support
- CAS (GR8s) from RAF Wittering, deployed to an undisclosed 5 ATAF field location
- CAS / CAP support (CF18s) from 4 Wing, deployed to an undisclosed 5 ATAF DOB

Currently, the helicopter unit is located some 40 km North of the objective area, at the Hersey Corner Airstrip (GL 100792).

The MNB has secured (albeit loosely) a number key areas, important to the Op NOMAD advance. These include:

- bridges at:

	Bridge Name
• GL 091499	105

• GL 093466	106
• GL 099450	107
• GL 088433	109
• GL 089415	110

- choke points at:

	Choke Point Name
• GL 079370	204
• GL 017395	205
• FL 993403	206
• GL 226436	207

It is 0830 and you have been informed that you are required to complete a mission of significant importance. The mission needs to be done quickly since the momentum of the MNB push through the territory may be halted as a result of possible FDN activity.

The HQ has lost contact with a patrol securing the choke point at GL 079370. The last report from the patrol indicated that they had observed increased vehicular traffic and massing of Armd unit(s) to the South of their objective. It is extremely important that the HQ determine the status of the choke point and if the FDN are attempting to advance North.

Pre Flt Brief to Crew from Ops

Situation:

General:

- as per intro

En:

- en activity in area of GL 079370 (objective) (last contact by patrol in area)
- contract report - sniper activity in area GL 193431 - 3 hrs ago
- contact report - en patrol raided village in area of GL 2243 - 8 hrs ago, appeared to be headed West

Fr:

- Recce Tp located in area GL 0345 (6 x HUM TOW)
- Arty Bty located at FL 050503 (8 x M109-A6)
- Inf Platoon located at GL 107440 (camouflaged tents)
- Patrol on bridge at GL 088433 (4 x M2A3 BRADLEY)
- attached for duration of mission - W Bty through G24
- CAS on call from MAGIC (10 min. notice required)

Wx:

- 5000 OVC, 4 NM vis, localized drizzle, temp 15°, dewpoint 10°, pressure 29.95”
- sunrise: 1200Z, sunset: 0300Z

Airspace:

- restrictions as per ACO

Mission:

Gain observation on the choke point at GL 079370 (objective) to determine en activity and continue to observe until T43B elements arrive.

Execution:

General Outline:

- In line with the mission, you have three objectives:

4. gain observation onto the choke point
5. determine if there is any en advance to / beyond the choke point
6. maintain observation until T43B arrives

Groupings and Tasks:

- You will be the sole CH146 equipped with ERSTA on the mission

Fire Support:

- arty is available on call throughout the mission through G24
- CAS is available through MAGIC on 10 min notice

AD Assets:

- 1 x M2A3 BRADLEY is located at FL 954438 (5 km Radius down to 50')

Co-ord Inst:

- timings: depart on mission NLT 0930
- route: as per ACO
- upon passing RP contact Bde HQ (C/S 92) and advise of ETA on observation area
- maintain contact with 92 through-out Recce phase

Service Support:

- FARP at GL 141461(open 1000-1030) - fuel only (HEMTT Fuel Bowser)
- FSH located at GL 098630
- pers eqpt - SOP

Command and Signals:

Command:

- UC 408 Sqn B Flt
- TACCON Bde HQ (C/S 92)

Codewords:

- objective under observation TELEPHOTO
- objective secure from en LOCKDOWN
- en movement North of objective GALLOP

COMMs:

- as per CEOIs

Airspace Control Orders

A special helicopter corridor has been reserved for this mission:

	Co-ord Point	Location	Altitude	Time (Z)
Ingress	ROCKWELL STREAM BRIDGE	GL 013734	< 500'	0930 -1000
	KNOWLTON HILL	GL 060587		
	BIG BOG	FL 997517		
RP	RODDYS LAKE	GL 043443	< 250'	N/A
Egress	LYON BRIDGE ROAD	GL 096451	< 500'	1000 -1100
	KNOWLTON HILL	GL 060587		
	ROCKWELL STREAM BRIDGE	GL 013734		

The area in the vicinity of the objectives has been co-ordinated with MNB HQ to be restricted from other friendly helicopter activity except for emergency operations and enemy contact. The Restricted Operations Zone (ROZ) is capped at 250' and is bounded by:

- GL 074333
- FL 985393
- FL 976430
- GL 135366

There is an active LLTR immediately West of the objective choke point, passing immediately above the ROZ (250'-500'), one way, headed NNE. It is expected that some friendly fighter activity may be using the LLTR on egress from BAI missions in FDN held territory SW of the St John River. The LLTR is aligned with:

- FL 9926 and FL 209778

All aircraft activity in the territory is co-ordinated with AWAC (Magic). Upon passing any co-ord point or release point a call is to be made indicating your callsign and the point you passing.

PL TROUT

FL 890720, FL 964686, GL 107728, GL 210779

PL PERCH

FL 909501, GL 060587, GL 173569, GL 253590

PL BASS

FL 900320, GL 017395, GL 096451, GL 260486

PL LION

FL 931738, FL 898560, GL 010310

PL TIGER

GL 237383, GL 167607, GL 138797

Communications Electronic Operating Instructions:

COMMs:

Unit	C/S	Freq	Crypto
AWAC	MAGIC	HQII / A89.625	No
Bde HQ	92	46.25	Fill 5
Patrol	I22A	39.80	Fill 4
Arty	G24	34.50	Fill 3
Recce Tp	T43B	48.65	Fill 2
Flt Ops	0	49.90	Fill 1
FARP	52D	46.50	Fill 1
CAS (on call)	HAWK	HQII / A67.125	No

IFF:

IFF Mode	Time	Code
Mode 1:	0900-0930	73
	0930-1000	61
	1000-1030	53
	1030-1100	41
	1100-1130	10
	1130-1200	70
Mode 2:	N/A	1324
Mode 3:	1200	
Mode 4:	0000z-1200z	A
	1200z-2400z	B

Experimenter Inputs:

The sortie will commence with the Griffon safely airborne at the 2nd pre-planned Co-ordination Point, at an altitude of 400 feet AGL, on track and heading to the next Co-ordination Point. Once the aircrew is comfortable the simulation will be uncaged; the time will be 0945Z.

Experimenter Inputs (NOT FOR EXPERT USER CONSUMPTION):

These activities are **NOT** briefed to the crew – in order to allow the aircrew to interact with the dynamic of the synthetic environment and react accordingly.

The following dynamic events will be programmed to occur during the “sortie”:

- 6 x M1A2 Abrams MBTs will transit WSW on the road from GL 040497 to FL 991481. The Abrams need to be moving as the helicopter is transiting to, but short of BIG BOG.
- A burning M939A2 5-Ton Truck will be on the ground at GL 067451.
- 6 x BTR 80s will transit North on the road from GL 100336 to GL 079368. The BTRs need to be moving as the Griffon reaches RODDYS LAKE.

TAMSS SA – EXPERIMENT #3 – <u>ZONE RECCE #3</u>

Tactical Scenario - Peace Support Operations

It is day 10 of Op NOMAD. Op NOMAD is the UN counteroffensive to push the final elements of the FDN troops out of the territory formerly known as Gagetownia. The FDN troops have been invading this territory for the past 10 months, conducting sporadic attacks on innocent civilians in an attempt to drive them out of the territory. Recently, in the past two months, the attacks have increased in number and in ferocity.

A number of emergency UN meetings have occurred resulting in a UN Chapter 6 operation (Op NOMAD) with the main objective to force the FDN troops out of the territory and allow the local Gagetownians to live in peace.

The FDN are a well equipped para-military organization who have been trained by Soviet forces, having been occupied as a soviet state for many years. Their equipment is predominantly Soviet based.

Future MNB operations require a number of critical areas to be maintained intact for the UN troops to continue the push to the North and West of the St John River. These key areas are the bridges West of Otnabog Lake and choke points on the West side of the St John river, used by the FDN for their initial incursion some 10 months ago.

The UN force is being led by the UN Multi-National Brigade (UNMNB) under the command of BGen Stanlowski (callsign Grimace) from Poland. The main UN offensive has pushed the main FDN forces out of the territory. However, it is expected that a number of layback patrols have remained in the area to disrupt the UN operation and slow down the advance. This will allow time for the FDN forces to regroup and attempt to re-start their guerrilla activities.

Canada has provided the following forces:

- a Mech Inf Coy (A Coy 2PPCLI) attached to a UK Inf Bn
- a Recce Tp (A Tp LdSH) attached to a GE armoured unit
- a helicopter Flt (B Flt 408 Sqn) assigned to MNB HQ
- fighter assets from 4 Wing Cold Lake

Other UN assets of importance include:

- Arty (MLRS) and Armd (Leo 2) from the German 5 Spa-Panzer Div (SPD)
- UK Arty Bn (21st FA)
- US Inf Bn (2 Bn 1 ID)
- AWAC support
- CAS (GR8s) from RAF Wittering, deployed to an undisclosed 5 ATAF field location
- CAS / CAP support (F18s) from 4 Wing, deployed to an undisclosed 5 ATAF DOB

Currently, the helicopter unit is located some 35 km South West of Black Clarendon (FL 8521).

The MNB has secured (albeit loosely) a number key areas, important to the Op NOMAD advance. These include:

- bridges at:

	Bridge Name
• GL 170651	111
• GL 187647	112
• GL 196652	113
• GL 207649	114

- choke points at:

	Choke Point Name
• GL 204704	208
• GL 174710	209
• GL 139640	210
• GL 085735	211
• GL 041633	212
• GL 197657	213

You are a Griffon crew assigned to conduct Recce tasks with the newly equipped ERSTA system. The Comd UNMNB has been impressed with the support provided to date since the ERSTA is the best long range rapidly deployable Recce system available in the Bde. The ERSTA equipped Griffons played a key roll in aiding the rapid advance of the MNB in the past 7 days.

It is 0830 and you have been informed that you are required to complete a mission of significant importance. The mission needs to be done quickly since the momentum of the MNB push through the territory may be halted as a result of possible FDN activity.

The HQ has lost contact with a patrol securing the bridges leading to the choke point / objective area at GL 197657. The last report from the patrol indicated that they had taken mortar fire at sporadically from the North and West of their positions. It is extremely important that the HQ determine the status of the bridges and the choke point, and if the FDN are attempting to mine or destroy the bridges and /or advance South through the choke point.

Pre Flt Brief to Crew from Ops

Situation:

General:

- as per intro

En:

- likely en activity in area of GL 197657 (objective) (last contact by patrol in area)
- contract report - sniper activity in area GL 1774 - 8 hrs ago
- intsum – ZSU-234 activity at Tantawanta Bridge - 4 hrs ago
- contact report - en patrol raided village in area of Fentons - 6 hrs ago, appeared to be headed North West

Fr:

- Recce Tp located in area GL 1472 (6 x HUM TOW)
- MLRS Bty located at GL 135585 (6 x M270 MLRS)
- Inf located at GL 210610 (camouflaged tents)
- Patrol at road intersection GL 178629 (4 x HUM AVENGER)
- attached for duration of mission - W Bty through G24
- CAS on call from MAGIC (10 min. notice required)

Wx:

- 5000 OVC, 4 NM vis, localized drizzle, temp 15°, dewpoint 10°, pressure 29.95”
- sunrise: 1200Z, sunset: 0300Z

Airspace:

- restrictions as per ACO

Mission:

Gain observation on the key bridges, determine if intact and observe the choke point at GL 197657 until T43B elements arrive.

Execution:

General Outline:

- In line with the mission, you have three objectives:

7. gain observation onto the key bridges
8. determine if the bridges are intact
9. maintain observation on the choke point until T43B arrives

Groupings and Tasks:

- You will be the sole CH146 equipped with ERSTA on the mission

Fire Support:

- MLRS is available on call throughout the mission through G24
- CAS is available through MAGIC on 10 min notice

AD Assets:

- 1 x M2A3 BRADLEY is located at GL 249634(5 km Radius down to 50’)

Co-ord Inst:

- timings: depart on mission NLT 0930
- route: as per ACO
- upon passing RP contact Bde HQ (C/S 92) and advise of ETA on observation area
- maintain contact with 92 through-out Recce phase

Service Support:

- FARP at GL 068548 (open 1000-1030) - fuel only (HEMTT Fuel Bowser)
- FSH located at GL 023485
- pers eqpt - SOP

Command and Signals:

Command:

- UC 408 Sqn B Flt
- TACCON Bde HQ (C/S 92)

Codewords:

• objective under observation	WINDSCREEN
• all bridges intact	FANCY
• any bridge destroyed	BITTER
• en movement South of choke point	LOCOMOTIVE

COMMs:

- as per CEOIs

Airspace Control Orders

A special helicopter corridor has been reserved for this mission:

	Co-ord Point	Location	Altitude	Time (Z)
Ingress	BLACK CLAREDON	FL 902340	< 500'	0930 -1000
	WELLSFORD	GL 078370		
	BELL BRIDGE RUIN	GL 097496		
RP	DAY HILL	GL 193545	< 250'	N/A
Egress	MALLORY-KERR ROADS	GL 106578	< 500'	1000 -1100
	WELLSFORD	GL 078370		
	BLACK CLAREDON	FL 902340		

The area in the vicinity of the objectives has been co-ordinated with MNB HQ to be restricted from other friendly helicopter activity except for emergency operations and enemy contact. The Restricted Operations Zone (ROZ) is capped at 250' and is bounded by:

- GL 120627
- GL 114683
- GL 232684
- GL 212622

There is an active LLTR immediately West of the objective bridge, passing immediately above the ROZ (250'-500'), one way, headed SSE. It is expected that some friendly fighter activity may be using the LLTR on egress from BAI missions in FDN held territory North of the St John River. The LLTR is aligned with:

- GL 127820 and GL 200320

All aircraft activity in the territory is co-ordinated with AWAC (Magic). Upon passing any co-ord point or release point a call is to be made indicating your callsign and the point you passing.

PL RAM

FL 891789, FL 992740, GL 150734, FL 262669

PL STEER

FL 903627, GL 023570, GL 193502, GL 262477

PL HOG

FL 898419, FL 947442, GL 078370, GL 230337

PL ROD

FL 992740, GL 041633, GL 048500, GL 000333

PL REEL

GL 243792, GL 262669, GL 262447, GL 230337

<u>Communications Electronic Operating Instructions</u>:

COMMs:

Unit	C/S	Freq	Crypto
AWAC	MAGIC	HQII / A73.925	No
Bde HQ	92	36.25	Fill 5
Patrol	I22A	59.80	Fill 3
Arty	G24	33.90	Fill 4
Recce Tp	T43B	42.65	Fill 1
Flt Ops	0	49.90	Fill 2
FARP	52D	46.50	Fill 2
CAS (on call)	TIGER	HQII / A48.625	No

IFF:

IFF Mode	Time	Code
Mode 1:	0900-0930	03
	0930-1000	51
	1000-1030	73
	1030-1100	41
	1100-1130	30
	1130-1200	00
Mode 2:	N/A	1324
Mode 3:	1200	
Mode 4:	0000z-1200z	A
	1200z-2400z	B

Experimenter Inputs:

The sortie will commence with the Griffon safely airborne at the 2nd pre-planned Co-ordination Point, at an altitude of 400 feet AGL, on track and heading to the next Co-ordination Point. Once the aircrew is comfortable the simulation will be uncaged; the time will be 0945Z.

Experimenter Inputs (NOT FOR EXPERT USER CONSUMPTION):

These activities are **NOT** briefed to the crew – in order to allow the aircrew to interact with the dynamic of the synthetic environment and react accordingly.

The following dynamic events will be programmed to occur during the “sortie”:

- 6 x M110 SP Howitzers will transit NNE on the road from GL 154508 to GL 169537. The M110s need to be moving as the helicopter is transiting between BELL BRIDGE RUIN and DAY HILL.

- A landed MI-28 Havoc will be on the ground at GL 209629.

- 4 x T-72 MBTs will transit South on the road from GL 203703 to the choke point / objective at GL 197657. The MBTs need to be moving as the Griffon reaches DAY HILL.

TAMSS SA – EXPERIMENT #3 – ZONE RECCE #4

Tactical Scenario - Peace Support Operations

It is day 10 of Op NOMAD. Op NOMAD is the UN counteroffensive to push the final elements of the FDN troops out of the territory formerly known as Gagetownia. The FDN troops have been invading this territory for the past 8 months, conducting sporadic attacks on innocent civilians in an attempt to drive them out of the territory. Recently, in the past month, the attacks have increased in number and in ferocity.

A number of emergency UN meetings have occurred resulting in a UN Chapter 6 operation (Op NOMAD) with the main objective to force the FDN troops out of the territory and allow the local Gagetownians to live in peace.

The FDN are a well equipped para-military organization who have been trained by Soviet forces, having been occupied as a soviet state for many years. Their equipment is predominantly Soviet based.

Future MNB operations require a number of critical areas to be maintained intact for the UN troops to continue the push West and North of the St John River. These key areas are the bridges and access routes crossing the Oromocto and St. John (West of Gagetown) Rivers leading to the main incursion points used by the FDN for their initial invasion some 8 months ago.

The UN force is being led by the UN Multi-National Brigade (UNMNB) under the command of BGen Leboeuf (callsign Roaster) from France. The main UN offensive has pushed the main FDN forces out of the territory. However, it is expected that a number of layback patrols have remained in the area to disrupt the UN operation and slow down the advance. This will allow time for the FDN forces to regroup and attempt to re-start their guerrilla activities.

Canada has provided the following forces:

- a Mech Inf Coy (A Coy 2PPCLI) attached to a UK Inf Bn
- a Recce Tp (A Tp LdSH) attached to a GE armoured unit
- a helicopter Flt (B Flt 408 Sqn) assigned to MNB HQ
- fighter assets from 4 Wing Cold Lake

Other UN assets of importance include:

- Arty (M109) and Armd (Leo 2) from the German 5 Spa-Panzer Div (SPD)
- UK Arty Bn (21^{st} FA)
- US Inf Bn (2 Bn 1 ID)
- AWAC support
- CAS (GR8s) from RAF Wittering, deployed to an undisclosed 5 ATAF field location
- CAS / CAP support (F18s) from 4 Wing, deployed to an undisclosed 5 ATAF DOB

Currently, the helicopter unit is located some 40 km South East of the objective area, at the Blue Mountain Correctional Facility (GL 223453).

The MNB has secured (albeit loosely) a number key areas, important to the Op NOMAD advance. These include:

- bridges at:

	Bridge Name
• FL 904710	115
• FL 926797	116
• FL 929804	117
• FL 978822	118
• <u>FL 960725</u>	119
• FL 970777	120
• FL 996724	121

- choke points at:

	Choke Point Name
• FL 988780	214
• FL 978775	215
• FL 963752	216
• FL 996717	217

You are a Griffon crew assigned to conduct Recce tasks with the newly equipped ERSTA system. The Comd UNMNB has been impressed with the support provided to date since the ERSTA is the best long range rapidly deployable Recce system available in the Bde. The ERSTA equipped Griffons played a key roll in aiding the rapid advance of the MNB in the past 6 days.

It is 0830 and you have been informed that you are required to complete a mission of significant importance. The mission needs to be done quickly since the momentum of the MNB push through the territory may be halted as a result of possible FDN activity.

The HQ has lost contact with a patrol securing the bridge at <u>FL 960725</u>. The last report from the patrol indicated that they had been fired at sporadically from the buildings to the South West of their positions. It is extremely important that the HQ determine the status of the bridge and if the FDN are attempting to mine or destroy the bridge.

Pre Flt Brief to Crew from Ops

Situation:

General:

- as per intro

En:

- likely en activity in area of FL 960725 (objective) (last contact by patrol in area)
- contract report - sniper activity in area FL 8980 - 4 hrs ago
- intsum – 2S6 activity in the area of Wood Meadow - 6 hrs ago
- contact report - en patrol raided village in area of Lower Lincoln - 6 hrs ago, appeared to be headed North West

Fr:

- Recce Tp located in area FL 9866 (6 x HUM TOW)
- MLRS Bty located at FL 982652 (6 x M270 MLRS)
- Inf located at FL 994770 (camouflaged tents)
- Patrol on bridge at FL 996724 (1 x M2A3 BRADLEY + 3 x HUM AVENGER)
- attached for duration of mission - W Bty through G24
- CAS on call from MAGIC (10 min. notice required)

Wx:

- 5000 OVC, 4 NM vis, localized drizzle, temp 15°, dewpoint 10°, pressure 29.95”
- sunrise: 1200Z, sunset: 0300Z

Airspace:

- restrictions as per ACO

Mission:

Gain observation on the bridge at FL 960725 to determine if the bridge is intact and observe the bridge until T43B elements arrive.

Execution:

General Outline:

- In line with the mission, you have three objectives:

10. gain observation onto the bridge
11. determine if the bridge is intact
12. maintain observation until T43B arrives

Groupings and Tasks:

- You will be the sole CH146 equipped with ERSTA on the mission

Fire Support:

- arty is available on call throughout the mission through G24
- CAS is available through MAGIC on 10 min notice

AD Assets:

- 1 x M2A3 BRADLEY is located at FL 960650 (5 km Radius down to 50')

Co-ord Inst:

- timings: depart on mission NLT 0930
- route: as per ACO
- upon passing RP contact Bde HQ (C/S 92) and advise of ETA on observation area
- maintain contact with 92 through-out Recce phase

Service Support:

- FARP at GL 098722 (open 1000-1030) - fuel only (HEMTT Fuel Bowser)
- FSH located at FL 195545
- pers eqpt - SOP

Command and Signals:

Command:

- UC 408 Sqn B Flt
- TACCON Bde HQ (C/S 92)

Codewords:

- objective under observation ZOOM
- objective intact HARVEST
- objective destroyed RECOIL

COMMs:

- as per CEOIs

Airspace Control Orders

A special helicopter corridor has been reserved for this mission:

	Co-ord Point	Location	Altitude	Time (Z)
Ingress	CENTRAL HAMPSTEAD	GL 250590	< 500’	0930 -1000
	LAWFIELD-BOUNDARY ROADS	GL 139640		
	NW KNOWLTON HILL	GL 048609		
RP	BROAD ROAD CLEARING	FL 984636	< 250’	N/A
Egress	LAUVINA ROAD CLEARING	GL 006703	< 500’	1000 -1100
	LAWFIELD-BOUNDARY ROADS	GL 139640		
	CENTRAL HAMPSTEAD	GL 250590		

The area in the vicinity of the objectives has been co-ordinated with MNB HQ to be restricted from other friendly helicopter activity except for emergency operations and enemy contact. The Restricted Operations Zone (ROZ) is capped at 250’ and is bounded by:

- FL 920678
- FL 936792
- FL 975782
- FL 973700
- FL 945672

There is an active one way LLTR South of the objective bridge, headed ENE and passing immediately South of the ROZ (SFC to < 500’. It is expected that some friendly fighter activity may be using the LLTR on egress from BAI missions in FDN held territory West of the objective. The LLTR is aligned with:

- FL 8564 and GL 2575

All aircraft activity in the territory is co-ordinated with AWAC (Magic). Upon passing any co-ord point or release point a call is to be made indicating your callsign and the point you passing.

PL SLEET

FL 920832, GL 094835, GL 195794, GL 262669

PL HAIL

FL 901620, GL 171502, GL 249369

PL WAVE

FL 960410, FL 908510, FL 897561, FL 920832

PL RIPPLE

GL 070305, GL 097496, GL 141579, GL 139640, GL 243793

Communications Electronic Operating Instructions:

COMMs:

Unit	C/S	Freq	Crypto
AWAC	MAGIC	HQII / A11.125	No
Bde HQ	92	37.85	Fill 5
Patrol	I12A	58.50	Fill 1
Arty	G24	34.50	Fill 3
Recce Tp	T43B	30.65	Fill 2
Flt Ops	0	49.90	Fill 4
FARP	52S	46.50	Fill 4
CAS (on call)	STING	HQII / A55.525	No

IFF:

IFF Mode	Time	Code
Mode 1:	0900-0930	13
	0930-1000	41
	1000-1030	23
	1030-1100	61
	1100-1130	70
	1130-1200	21
Mode 2:	N/A	1721
Mode 3:	1200	
Mode 4:	0000z-1200z	A
	1200z-2400z	B

Experimenter Inputs:

The sortie will commence with the Griffon safely airborne at the 2nd pre-planned Co-ordination Point, at an altitude of 400 feet AGL, on track and heading to the next Co-ordination Point. Once the aircrew is comfortable the simulation will be uncaged; the time will be 0945Z.

Experimenter Inputs (NOT FOR EXPERT USER CONSUMPTION):

These activities are **NOT** briefed to the crew – in order to allow the aircrew to interact with the dynamic of the synthetic environment and react accordingly.

The following dynamic events will be programmed to occur during the "sortie":

- 5 x M1045 HHMWV TOWs will transit NW on the black track from FL 983614 to FL 968640. The TOWs need to be moving as the helicopter is transiting NW KNOWLTON HILL.

- A burning/crashed SU-25 Frogfoot will be on the ground at FL 930697.

- 4 x ZSU-234s will transit South on the road from FL 965765 to FL 963746. The ZSU-234s need to be moving as the Griffon reaches BROAD ROAD CLEARING.

ANNEX B

Mission Assessment Questionnaires

TAMSS Experiment 3

Mission Assessment
Flying Pilot Version

Participant ID	
Date	
Time	
Mission number	
Scenario Code	
Condition	MS present Or MS not present

Instructions

If you have additional comments about any question or item, please write these on the back of the corresponding page.

M1. **Rate how well you performed of each of the following tasks during THIS mission. Circle N/A if the item was not applicable to this mission.**

	PERFORMANCE							
Task	very poor			adequate			very good	
Finding waypoints	1	2	3	4	5	6	7	NA
Control heading	1	2	3	4	5	6	7	NA
Control altitude	1	2	3	4	5	6	7	NA
Control airspeed	1	2	3	4	5	6	7	NA
Cross checking relevant instruments/symbology	1	2	3	4	5	6	7	NA
Positioning the aircraft in recce area	1	2	3	4	5	6	7	NA
Maintaining tactical flight	1	2	3	4	5	6	7	NA

M2. Rate the difficulty of each of the following tasks during <u>THIS</u> mission. Circle N/A if the item was not applicable to this mission.

	DIFFICULTY							
Task	very easy			moderate			very difficult	
Finding waypoints	1	2	3	4	5	6	7	NA
Control heading	1	2	3	4	5	6	7	NA
Control altitude	1	2	3	4	5	6	7	NA
Control airspeed	1	2	3	4	5	6	7	NA
Cross checking relevant instruments/symbology	1	2	3	4	5	6	7	NA
Positioning the aircraft in recce area	1	2	3	4	5	6	7	NA
Maintaining tactical flight	1	2	3	4	5	6	7	NA

M3. Rate your awareness of the status of the aircraft systems as it applies to <u>THIS</u> mission/task.

	AWARENESS							
	very low			moderate			very high	
Aircraft Systems overall	1	2	3	4	5	6	7	NA
Heading	1	2	3	4	5	6	7	NA
RAD Alt	1	2	3	4	5	6	7	NA
Airspeed	1	2	3	4	5	6	7	NA
Attitude	1	2	3	4	5	6	7	NA

M4. **Rate your awareness of tactical information relevant to <u>THIS</u> mission (i.e. where do you need to go and what needs to be completed, mission goals and how is the mission unfolding).**

	AWARENESS							
	very low			moderate			very high	
Overview of mission	1	2	3	4	5	6	7	NA
Unfolding of mission/keeping track of how mission unfolds	1	2	3	4	5	6	7	NA
Potential developments (anticipating future scenarios)	1	2	3	4	5	6	7	NA
Global mission goals	1	2	3	4	5	6	7	NA
Specific mission goals	1	2	3	4	5	6	7	NA
Enemy activities	1	2	3	4	5	6	7	NA
Friendly activities	1	2	3	4	5	6	7	NA
General threat	1	2	3	4	5	6	7	NA
Where I need to go	1	2	3	4	5	6	7	NA

M5. Rate your spatial/navigational awareness (i.e. where you need to go and location of ownship in relation to enemies, friendly units, target and other relevant objects and landmarks in the environment) during <u>THIS</u> mission.

	AWARENESS							
	very low			moderate			very high	
Overall Spatial Orientation	1	2	3	4	5	6	7	NA
Ownship location in relation to target (e.g. bridge)	1	2	3	4	5	6	7	NA
Ownship location in relation to enemy activity	1	2	3	4	5	6	7	NA
Ownship location in relation to friendly activity	1	2	3	4	5	6	7	NA
Target location relative to enemy and friendly units	1	2	3	4	5	6	7	NA
Important landmarks	1	2	3	4	5	6	7	NA
General layout of the navigated area	1	2	3	4	5	6	7	NA

M6. Rate the following crew activity during THIS mission.

	very low			moderate			very high	
Overall **quality** of communication	1	2	3	4	5	6	7	NA
The **usefulness** of information provided by Mission Commander	1	2	3	4	5	6	7	NA
The **usefulness** of information provided by the ERSTA operator	1	2	3	4	5	6	7	NA
Ability to **convey** information to Mission Commander	1	2	3	4	5	6	7	NA

M7. **Rate your workload during <u>THIS</u> mission. Circle NA if not applicable during this mission.**

	WORKLOAD							
	very low			moderate			very high	
Planning the route?	1	2	3	4	5	6	7	NA
Finding waypoints	1	2	3	4	5	6	7	NA
Positioning the aircraft in the recce zone	1	2	3	4	5	6	7	NA
Radio communications	1	2	3	4	5	6	7	NA
Monitoring friendly activity	1	2	3	4	5	6	7	NA
Monitoring enemy activity	1	2	3	4	5	6	7	NA
Monitoring general threats	1	2	3	4	5	6	7	NA
Ingress to first waypoint	1	2	3	4	5	6	7	NA
First waypoint to release point (RP)	1	2	3	4	5	6	7	NA
Recce zone [release point to target]	1	2	3	4	5	6	7	NA
Egress [target to end]	1	2	3	4	5	6	7	NA
Overall	1	2	3	4	5	6	7	NA
Communication with Mission Commander	1	2	3	4	5	6	7	NA

At any point, did you find that your workload was very different (e.g., much higher or lower) than across the mission as a whole? YES or NO

If yes, please elaborate:

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If at any point you found that your workload was very different, what aspects of your tasks (e.g., radio communication, using information to control aircraft, flying aircraft, etc.) were affected?

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TLX WORKLOAD ASSESSMENT

Instructions. Place an X on each scale at the point that represents the magnitude for each factor in the mission you just performed. Refer to the Workload Scale Descriptions for definitions of each factor.

SEGMENT OF MISSION: **Ingress to release point**

Mental demand	LOW	|----|----|----|----|----|----|----|----|----|----|	HIGH
Physical demand	LOW	|----|----|----|----|----|----|----|----|----|----|	HIGH
Temporal demand	LOW	|----|----|----|----|----|----|----|----|----|----|	HIGH
Frustration level	LOW	|----|----|----|----|----|----|----|----|----|----|	HIGH
Effort	LOW	|----|----|----|----|----|----|----|----|----|----|	HIGH
Performance	POOR	|----|----|----|----|----|----|----|----|----|----|	GOOD

SEGMENT OF MISSION: **Release point to first observation point**

Mental demand	LOW	|----|----|----|----|----|----|----|----|----|----|	HIGH
Physical demand	LOW	|----|----|----|----|----|----|----|----|----|----|	HIGH
Temporal demand	LOW	|----|----|----|----|----|----|----|----|----|----|	HIGH
Frustration level	LOW	|----|----|----|----|----|----|----|----|----|----|	HIGH
Effort	LOW	|----|----|----|----|----|----|----|----|----|----|	HIGH
Performance	POOR	|----|----|----|----|----|----|----|----|----|----|	GOOD

SEGMENT OF MISSION: **Getting and maintaining observation of target**

Mental demand LOW |----|----|----|----|----|----|----|----|----|----| HIGH

Physical demand LOW |----|----|----|----|----|----|----|----|----|----| HIGH

Temporal demand LOW |----|----|----|----|----|----|----|----|----|----| HIGH

Frustration level LOW |----|----|----|----|----|----|----|----|----|----| HIGH

Effort LOW |----|----|----|----|----|----|----|----|----|----| HIGH

Performance POOR |----|----|----|----|----|----|----|----|----|----| GOOD

SEGMENT OF MISSION: **Overall activity while in the Recce zone**

Mental demand LOW |----|----|----|----|----|----|----|----|----|----| HIGH

Physical demand LOW |----|----|----|----|----|----|----|----|----|----| HIGH

Temporal demand LOW |----|----|----|----|----|----|----|----|----|----| HIGH

Frustration level LOW |----|----|----|----|----|----|----|----|----|----| HIGH

Effort LOW |----|----|----|----|----|----|----|----|----|----| HIGH

Performance POOR |----|----|----|----|----|----|----|----|----|----| GOOD

SEGMENT OF MISSION: **Egress**

Mental demand	LOW	|----|----|----|----|----|----|----|----|----|----|	HIGH
Physical demand	LOW	|----|----|----|----|----|----|----|----|----|----|	HIGH
Temporal demand	LOW	|----|----|----|----|----|----|----|----|----|----|	HIGH
Frustration level	LOW	|----|----|----|----|----|----|----|----|----|----|	HIGH
Effort	LOW	|----|----|----|----|----|----|----|----|----|----|	HIGH
Performance	POOR	|----|----|----|----|----|----|----|----|----|----|	GOOD

TAMSS Experiment 3
Mission Assessment
Mission Commander Version

Participant ID	
Date	
Time	
Mission number	
Scenario Code	
Condition	MS present Or MS not present

Instructions

If you have additional comments about any question or item, please write these on the back of the corresponding page.

M1. Rate how well you performed on each of the following tasks during <u>THIS</u> mission. Circle N/A if the item was not applicable to this mission.

	PERFORMANCE							
Task	very poor			adequate			very good	
Finding waypoints	1	2	3	4	5	6	7	NA
Navigate	1	2	3	4	5	6	7	NA
Maintaining/following the route	1	2	3	4	5	6	7	NA
Using the CDU	1	2	3	4	5	6	7	NA
Using comms	1	2	3	4	5	6	7	NA
Use of sensor capability	1	2	3	4	5	6	7	NA
Use of digital map capabilities	1	2	3	4	5	6	7	NA
Communicating with the Mission specialist	1	2	3	4	5	6	7	NA
Guiding the Mission specialist to position the sensor	1	2	3	4	5	6	7	NA
Positioning the sensor	1	2	3	4	5	6	7	NA
Guiding the flying pilot to position the aircraft in recce zone	1	2	3	4	5	6	7	NA

M2. Rate the difficulty of each of the following tasks during <u>THIS</u> mission. Circle N/A if the item was not applicable to this mission.

	DIFFICULTY							
Task	very easy			moderate			very difficult	
Finding waypoints	1	2	3	4	5	6	7	NA
Navigate	1	2	3	4	5	6	7	NA
Maintaining/following the route	1	2	3	4	5	6	7	NA
Using the CDU	1	2	3	4	5	6	7	NA
Using comms	1	2	3	4	5	6	7	NA
Use of sensor capability	1	2	3	4	5	6	7	NA
Use of tactical map capabilities	1	2	3	4	5	6	7	NA
Communicating with the Mission specialist	1	2	3	4	5	6	7	NA
Guiding the Mission specialist to position the sensor	1	2	3	4	5	6	7	NA
Positioning the sensor	1	2	3	4	5	6	7	NA
Guiding the flying pilot to position the aircraft in recce zone	1	2	3	4	5	6	7	NA

M3. **Rate the difficulty of getting information from each of the following sources during <u>THIS</u> mission. Circle NA if not applicable to this mission.**

	DIFFICULTY							
	very easy			moderate			very difficult	
The ERSTA sensor	1	2	3	4	5	6	7	NA
The digital tactical map	1	2	3	4	5	6	7	NA
Mission Specialist	1	2	3	4	5	6	7	NA
CDU	1	2	3	4	5	6	7	NA

M4. Rate your awareness of tactical information relevant to your mission (i.e. where do you need to go and what needs to be completed, mission goals and how is the mission unfolding) during <u>THIS</u> mission.

	AWARENESS							
	very low			moderate			very high	
Overview of mission	1	2	3	4	5	6	7	NA
Keeping track of how mission unfolds	1	2	3	4	5	6	7	NA
Potential developments (anticipating future events)	1	2	3	4	5	6	7	NA
Global mission goals	1	2	3	4	5	6	7	NA
Specific mission goals	1	2	3	4	5	6	7	NA
Enemy activities	1	2	3	4	5	6	7	NA
Friendly activities	1	2	3	4	5	6	7	NA
General threats	1	2	3	4	5	6	7	NA
Where I need to go	1	2	3	4	5	6	7	NA

M5. Rate your spatial/navigational awareness (i.e. where you need to go and location of ownship in relation to enemies, friendly units, target and other relevant objects and landmarks in the environment) during <u>THIS</u> mission.

	AWARENESS							
	very low			moderate			very high	
Overall Spatial Orientation	1	2	3	4	5	6	7	NA
Ownship location in relation to objectives (e.g. bridge)	1	2	3	4	5	6	7	NA
Ownship location in relation to enemy activity	1	2	3	4	5	6	7	NA
Ownship location in relation to friendly activity	1	2	3	4	5	6	7	NA
Target location relative to enemy and friendly units	1	2	3	4	5	6	7	NA
Important landmarks	1	2	3	4	5	6	7	NA
General layout of the navigated area	1	2	3	4	5	6	7	NA
Information provided by the ERSTA system	1	2	3	4	5	6	7	NA

M6. Rate the following crew activity during THIS mission.

	very low			moderate			very high	
Overall **quality** of communication	1	2	3	4	5	6	7	NA
The **usefulness** of information provided by the Mission specialist	1	2	3	4	5	6	7	NA
Ability to **instruct** the Mission specialist	1	2	3	4	5	6	7	NA
Awareness of Mission specialist activity	1	2	3	4	5	6	7	NA
Ability to **convey** information to flying pilot	1	2	3	4	5	6	7	NA
Coordinating all tasks	1	2	3	4	5	6	7	NA
Coordinating communication	1	2	3	4	5	6	7	NA

M7. Rate your workload on each of the tasks performed during THIS mission

	WORKLOAD							
	very low			moderate			very high	
Communicating with flying pilot	1	2	3	4	5	6	7	NA
Communicating with the Mission specialist	1	2	3	4	5	6	7	NA
Navigating	1	2	3	4	5	6	7	NA
Maintaining/following the route	1	2	3	4	5	6	7	NA
Finding waypoints	1	2	3	4	5	6	7	NA
Guiding the flying pilot to position the aircraft in the recce zone	1	2	3	4	5	6	7	NA
Guiding the Mission specialist to position the sensor	1	2	3	4	5	6	7	NA
Positioning the sensor	1	2	3	4	5	6	7	NA
Operating CDU	1	2	3	4	5	6	7	NA
Radio communications	1	2	3	4	5	6	7	NA
Monitoring friendly activity	1	2	3	4	5	6	7	NA
Monitoring enemy activity	1	2	3	4	5	6	7	NA
Monitoring general threats	1	2	3	4	5	6	7	NA
Ingress to first waypoint	1	2	3	4	5	6	7	NA
First waypoint to release point (RP)	1	2	3	4	5	6	7	NA

Recce zone [release point to target]	1	2	3	4	5	6	7	NA
Egress [target to end]	1	2	3	4	5	6	7	NA
Overall	1	2	3	4	5	6	7	NA

TLX WORKLOAD ASSESSMENT

Instructions. Place an X on each scale at the point that represents the magnitude of each factor in the mission you just performed. Refer to the Workload Scale Descriptions for definitions of each factor.

SEGMENT OF MISSION: **Ingress to release point**

Mental demand LOW |----|----|----|----|----|----|----|----|----|----| HIGH

Physical demand LOW |----|----|----|----|----|----|----|----|----|----| HIGH

Temporal demand LOW |----|----|----|----|----|----|----|----|----|----| HIGH

Frustration level LOW |----|----|----|----|----|----|----|----|----|----| HIGH

Effort LOW |----|----|----|----|----|----|----|----|----|----| HIGH

Performance POOR |----|----|----|----|----|----|----|----|----|----| GOOD

SEGMENT OF MISSION: **Release point to first observation point**

Mental demand LOW |----|----|----|----|----|----|----|----|----|----| HIGH

Physical demand LOW |----|----|----|----|----|----|----|----|----|----| HIGH

Temporal demand LOW |----|----|----|----|----|----|----|----|----|----| HIGH

Frustration level LOW |----|----|----|----|----|----|----|----|----|----| HIGH

Effort LOW |----|----|----|----|----|----|----|----|----|----| HIGH

Performance POOR |----|----|----|----|----|----|----|----|----|----| GOOD

SEGMENT OF MISSION: **Getting and maintaining observation of target**

Mental demand LOW |----|----|----|----|----|----|----|----|----|----| HIGH

Physical demand LOW |----|----|----|----|----|----|----|----|----|----| HIGH

Temporal demand LOW |----|----|----|----|----|----|----|----|----|----| HIGH

Frustration level LOW |----|----|----|----|----|----|----|----|----|----| HIGH

Effort LOW |----|----|----|----|----|----|----|----|----|----| HIGH

Performance POOR |----|----|----|----|----|----|----|----|----|----| GOOD

SEGMENT OF MISSION: **Overall activity while in Recce zone.**

Mental demand LOW |----|----|----|----|----|----|----|----|----|----| HIGH

Physical demand LOW |----|----|----|----|----|----|----|----|----|----| HIGH

Temporal demand LOW |----|----|----|----|----|----|----|----|----|----| HIGH

Frustration level LOW |----|----|----|----|----|----|----|----|----|----| HIGH

Effort LOW |----|----|----|----|----|----|----|----|----|----| HIGH

Performance POOR |----|----|----|----|----|----|----|----|----|----| GOOD

SEGMENT OF MISSION: **Egress**

Mental demand LOW |----|----|----|----|----|----|----|----|----|----| HIGH

Physical demand LOW |----|----|----|----|----|----|----|----|----|----| HIGH

Temporal demand LOW |----|----|----|----|----|----|----|----|----|----| HIGH

Frustration level LOW |----|----|----|----|----|----|----|----|----|----| HIGH

Effort LOW |----|----|----|----|----|----|----|----|----|----| HIGH

Performance POOR |----|----|----|----|----|----|----|----|----|----| GOOD

Open-ended questions

When there was **no** Mission Specialist present, would you see value in having a Mission specialist?

YES or NO Please elaborate:

When there **was** a Mission Specialist present would you see value in not having a Mission specialist? YES or No Please elaborate:

Would it be beneficial to have a Mission Commander override for the ERSTA system? YES or NO

Please elaborate:

Was there a time when you needed to, but could not operate the sensor (e.g. the Mission specialist had locked the system) YES or NO

Please elaborate:

At any point, did you find that your workload was very different (e.g., much higher or lower) than across the mission as a whole? YES or NO

If yes, please elaborate:

If at any point you found that your workload was very different, what aspects of your tasks (e.g., radio communication, using information to control aircraft, flying aircraft, etc.) were affected?

ANNEX C

Background Questionnaire for Pilots

TAMSS Experiment 3 **Participant ID: __________**

Background Information: Pilots

This information helps us to determine whether we have recruited a broad sample of pilots. To get an unbiased understanding of the concerns of the operation community, we must get feedback from a cross-section of experience levels and backgrounds.

1. Age: ___________ (in years)
2. Years in CF: ___________
3. Years as a pilot: ________
4. TacHel experience: _________ (in years)
5. Rank: _________
6. Handedness: ____left OR ___ right

Estimated Flight Time

Type of Flight	**Estimated time (in hours)**
1. Total flight time	
2. Total rotary wing	
3. Total Griffon	
4. Time spent using a flight simulator	

Specify the type of simulator experiences that you have had:

____

____

____

Indicate any other experience (e.g. TacHel) that you believe may be relevant to your performance in this experiment.

____

____

ANNEX D

Background Questionnaire for Mission Specialist

TAMSS Experiment 3 **Participant ID: __________**

Background Information: Mission Specialist

This information helps us to determine whether we have recruited a broad sample of pilots. To get an unbiased understanding of the concerns of the operation community, we must get feedback from a cross-section of experience levels and backgrounds.

7. Age: __________ (in years)
8. Years in CF: __________
9. Years as a Mission specialist: _______
10. TacHel experience: ________ (in years)
11. MOC (Millitary Occupation Code): ________
12. Rank: ________
13. Handedness: ____left OR ___ right

Estimated Flight Time

Type of Flight	**Estimated time (in hours)**
2. Total rotary wing	
3. Total Griffon	
4. Time spent using a flight simulator	

Specify the type of simulator experiences that you have had:

____

____

____

Indicate any other experience (e.g. TacHel) that you believe may be relevant to your performance in this experiment.

____

____

ANNEX E

Summary Data: Mission Assessment Questionnaires

Summary of Post Mission Questionnaires
TAMSS Project - Experiment 2
Flying Pilot

Rated Performance

M1. Rate how well you performed of each of the following tasks during **THIS** mission. Circle N/A if the item was not applicable to this mission.
Average scores; poor (1-3), adequate (4) and good (5-7)
Average rated performance overall; MS present=5.107, MS not present=4.732

	MS present	MS not present
Finding waypoints	Adequate (4.375)	Adequate (4.625)
Control heading	Good (5.25)	Good (5)
Control altitude	Good (5.25)	Adequate (4.625)
Control airspeed	Good (5.625)	Adequate (4.625)
Cross checking relevant instrument/symbology	Adequate (4.875)	Adequate (4.875)
Positioning the aircraft in recce area	Good (5.375)	Adequate (4.625)
Maintaining tactical flight	Good (5)	Adequate (4.75)

Rated Task Difficulty

M2. Rate the difficulty of each of the following tasks during **THIS** mission. Circle N/A if the item was not applicable to this mission.
Average scores; easy (1-3), moderate (4) and difficult (5-7)
Average rated task difficulty overall; MS present=3.21, MS not present=3.23

	MS present	MS not present
Finding waypoints	Easy (2.75)	Easy (2.625)
Control heading	Easy (3.125)	Easy (3.125)
Control altitude	Easy (3.625)	Easy (3.375)
Control airspeed	Easy (2.75)	Easy (3)
Cross checking relevant instrument/symbology	Easy (3.125)	Easy (3.375)
Positioning the aircraft in recce area	Easy (3.375)	Easy (3.625)
Maintaining tactical flight	Easy (3.75)	Easy (3.5)

Rated Situation Awareness

M3. Rate your awareness of the status of the aircraft systems as it applies to **THIS** mission/task.
Average scores; low (1-3), moderate (4) and high (5-7)
Average rated situation awareness overall; MS present=5.625,
MS not present= 5.12

	MS present	MS not present
Aircraft systems overall	High (5.25)	Moderate (4.625)
Heading	High (5.5)	High (5)
RAD alt	High (6.125)	High (5.75)
Airspeed	High (5.375)	High (5)
Attitude	High (5.875)	High (5.25)

Rated tactical awareness

M4. Rate your awareness of tactical information relevant to **THIS** mission (i.e. where do you need to go and what needs to be completed, mission goals and how is the mission unfolding).
Average scores; low (1-3), moderate (4) and high (5-7)
Average rated tactical awareness overall; MS present=5.125, MS not present=5.166

	MS present	MS not present
Overview of mission	High (5.875)	High (5.375)
Unfolding of mission/keeping track of how mission unfolds	Moderate (5)	High (5)
Potential developments (anticipating future scenarios)	High (6)	Low (4.875)
Global mission goals	High (5.25)	High (5.125)
Specific mission goals	High (4.875)	High (5.125)
Enemy activities	Low (4.375)	High (4.375)
Friendly activities	Low (4.625)	Low (3.625)
General threat	Moderate (5.125)	Moderate (4)
Where I need to go	Low (5)	High (4.5)

Rated spatial awareness

M5. Rate your spatial/navigational awareness (i.e. where you need to go and location of ownship in relation to enemies, friendly units, target and other relevant objects and landmarks in the environment) during **THIS** mission.
Average scores; low (1-3), moderate (4) and high (5-7)
Average rated spatial awareness overall; MS present=4, MS not present=4.3928

	MS present	MS not present
Overall spatial orientation	Moderate (4.875)	High (5)
Ownship location in relation to target (e.g. bridge)	High (5.25)	Moderate (4.625)
Ownship location in relation to enemy activity	Moderate (4)	Moderate (4.375)
Ownship location in relation to friendly activity	NA	Low (3.625)
Target location relative to enemy and friendly units	Low (3.75)	Low (3.625)
Important landmarks	Moderate (4.75)	Moderate (4.625)
General layout of the navigated area	Low (5.375)	High (4.875)

Rated Crew activity

M6. Rate the following crew activity during **THIS** mission.
Average scores; low (1-3), moderate (4) and high (5-7)
Average rated crew activity overall; MS present=4.718, MS not present=3.84

	MS present	MS not present
Overall quality of communication	Moderate (4.875)	High (4.5)
The usefulness of information provided by Mission Commander	Moderate (4.75)	Moderate (4.625)
The **usefulness** of information provided by the ERSTA operator	Moderate (4.875)	Low (1.75)
Ability to **convey** information to Mission Commander	Moderate (4.375)	Moderate (4.5)

Rated Workload

M7. Rate your workload during **THIS** mission. Circle NA if not applicable for this mission.
Average scores; low (1-3), moderate (4) and high (5-7)
Average rated workload overall; MS present= 2.673, MS not present=3.115

	MS Present	MS not present
Planning the route?	Low (2.5)	Low (3.125)
Finding waypoints	Low (2.75)	Low (3.375)
Positioning the aircraft in the recce zone	Low (3.5)	Moderate (4)
Radio communications	Low (.875)	Low (1.25)
Monitoring friendly activity	Low (1.625)	Low (1.875)
Monitoring enemy activity	Low (2.875)	Moderate (4)
Monitoring general threats	Low (3.875)	Moderate (4)
Ingress to first waypoint	Low (1.875)	Low (2.125)
First waypoint to release point (RP)	Low (2)	Low (2.25)
Recce zone [release point to target]	Low (3.5)	Moderate (4)
Egress [target to end]	Low (2.375)	Low (3)
Overall	Low (3.375)	Low (3.875)
Communication with Mission Commander	Low (3.625)	Low (3.625)

Additional questions:

1. At any point, did you find that your workload was very different (e.g., much higher or lower) than across the mission as a whole? YES or NO
If yes, please elaborate:

P2: (MS not present) No. I fly where the Mission Commander tells me to fly.
P2: (MS present) No.
P3: (MS present) Yes. Moving into first and subsequent observation positions and keeping helicopter control while in NOE and masked locations.
P3: (MS not present) Yes. Need to provide input verbally to MC regarding my intent (i.e., where to best tactically position the aircraft). Also, proving suggestions of future intentions and possible best courses of action.
P4: (MS not present) Yes. Workload was higher when trying to get set up in the observation points.
P4: (MS present) Yes. A definite peak of workload just maintaining hover at observation point before the objective and also some work to ensure accurate position at other observation points.
P5: (MS present) No.
P5: (MS not present) Yes, when engaged by enemy fire.
P6: (MS present) Yes. During enemy engagements.
P6: (MS not present) No.
P7: (MS present) Yes. When flying across the "swamp" there were no references to indicate altitude, attitude, or groundspeed.
P7 (MS not present) Yes. In the hover, at times it was difficult to maintain height and position due to lack of references and sensitivity of flight controls.

2. If at any point you found that your workload was very different, what aspects of your tasks (e.g., radio communication, using information to control aircraft, flying aircraft, etc.) were affected?

P2: (MS not present) Sometimes there were lack of directions from the Mission Commander.
P3: (MS present) Fairly high workload to keep aircraft in correct position to allow sensor operator to view the target area.
P3 (MS not present) As above. Since MC was too heavily task-saturated to control mission, direct aircraft, or make radio calls. I was able to provide a wider SA of the situation while MC was focused on tasks. I had more autonomy to position aircraft into the best position.
P4: (MS not present) Flying the aircraft became a little more challenging.
P5: (MS not present) Flying the aircraft; navigation.
P6: (MS present) Controlling the aircraft to aid the ERSTA operator.
P7: (MS present) Flying aircraft across the "marsh" was very difficult due to lack of references.
P7 (MS not present) As indicated above. Control of aircraft in hover was difficult at times.

P8: (MS present) There was a lot of communication going on between MC and MS and it kept me from asking and getting information about where the enemy is in relation to aircraft.

TLX WORKLOAD ASSESSMENT

Instructions. Place an X on each scale at the point that represents the magnitude for each factor in the mission you just performed. Refer to the Workload Scale Descriptions for definitions of each factor.
Average scores; low (1-4), moderate (5) and high (6-10)

SEGMENT OF MISSION: **Ingress to release point**

	MS present	MS not present
Mental demand	2.0625	2.3125
Physical demand	2.1875	2.1875
Temporal demand	1.9375	2.0000
Frustration level	2.0625	1.8750
Effort	2.3750	2.0625
Performance	8.4375	8.3125

SEGMENT OF MISSION: **Release point to first observation point**

	MS present	MS not present
Mental demand	3.7500	3.5625
Physical demand	3.0000	3.5625
Temporal demand	3.0625	3.5000
Frustration level	1.9375	3.2500
Effort	3.6250	3.9375
Performance	7.9375	7.6875

SEGMENT OF MISSION: **Getting and maintaining observation of target**

	MS present	MS not present
Mental demand	4.1875	5.0625
Physical demand	3.8750	4.3750
Temporal demand	3.2500	5.1250
Frustration level	3.0625	4.6875
Effort	4.9375	5.3750
Performance	8.5000	6.6875

SEGMENT OF MISSION: **Overall activity while in the Recce zone**

	MS present	MS not present
Mental demand	4.8125	4.5000
Physical demand	4.0000	4.5000
Temporal demand	4.1250	4.3125
Frustration level	3.0000	4.0625
Effort	4.8750	5.6250
Performance	8.4375	7.1875

SEGMENT OF MISSION: **Egress**

	MS present	MS not present
Mental demand	2.6250	3.2500
Physical demand	2.5000	2.2500
Temporal demand	3.1875	2.7500
Frustration level	1.3750	2.4375
Effort	2.6875	3.1250
Performance	8.5625	8.5000

Summary of Post Mission Questionnaires TAMSS Project - Experiment 3
Mission Commander Rated Confidence in Re-creating Mission

Rated performance

M1. Rate how well you performed on each of the following tasks during **THIS** mission. Circle N/A if the item was not applicable to this mission.
Average scores; poor (1-3), adequate (4) and good (5-7)
Average rated performance overall; MS present=4.238, MS not present=2.875

	MS present	MS not present
Finding waypoints	Good (5.5)	Adequate (4.5)
Navigate	Good (5.625)	Adequate(4.625)
Maintaining/following the route	Good (5)	Adequate (4.5)
Using the CDU		
Using comms	Poor (3.125)	Poor (3.75)
Use of sensor capability	Adequate (4)	Adequate (3.125)
Use of digital map capabilities	Good (5.25)	Poor (3.875)
Communicating with the Mission specialist	Good (5.375)	NA
Guiding the Mission specialist to position the sensor	Good (5.75)	.NA
Positioning the sensor	Poor (1.5)	Poor (3)
Guiding the flying pilot to position the aircraft in recce zone	Good (5.5)	Adequate (4.25)

Rated Task Difficulty

M2. Rate the difficulty of each of the following tasks during **<u>THIS</u>** mission. Circle N/A if the item was not applicable to this mission.

Average scores; easy (1-3), moderate (4) and difficult (5-7)

Average rated task difficulty overall; MS present=2.383, MS not present=2.863

	MS present	MS not present
Finding waypoints	Easy (3.125)	Easy (3.5)
Navigate	Easy (2.875)	Easy (3.25)
Maintaining/following the route	Easy (2.5)	Easy (3.125)
Using the CDU	NA	NA
Using comms	Easy (1.875)	Easy (3.375)
Use of sensor capability	Easy (3)	Difficult (5.375)
Use of tactical map capabilities	Easy (3.5)	Easy (3.625)
Communicating with the Mission specialist	Easy (2.625)	NA
Guiding the Mission specialist to position the sensor	Easy (2.625)	NA
Positioning the sensor	Easy (1.375)	Difficulty (5.375)
Guiding the flying pilot to position the aircraft in recce zone	Easy (2.75)	Easy (3.875)

Rated difficulty getting information

M3. Rate the difficulty of getting information from each of the following sources during **<u>THIS</u>** mission. Circle NA if not applicable to this mission.

Average scores; easy (1-3), moderate (4) and difficult (5-7)

Average rated difficulty getting information overall; MS present- 2.214, MS not present= 2.09

	MS present	Ms not present
The ERSTA sensor	Easy (3.5)	Moderate (4.875)
The digital tactical map	Easy (2.8571)	Easy (3.5)
Mission Specialist	Easy (2.5)	NA
CDU	NA	NA

Rated Situation Awareness

M4. Rate your awareness of tactical information relevant to your mission (i.e. where do you need to go and what needs to be completed, mission goals and how is the mission unfolding) during **THIS** mission

Average scores; low (1-3), moderate (4) and high (5-7)

Average rated situation awareness overall; MS present= 5.375, MS not present= 4.43

	MS present	MS not present
Overview of mission	High (6)	High (5.125)
Unfolding of mission/keeping track of how mission unfolds	High (5.375)	Moderate (4.625)
Potential developments (anticipating future scenarios)	High (5.375)	Low (3.5)
Global mission goals	High (5.75)	Moderate (4.625)
Specific mission goals	High (5.5)	High (5.125)
Enemy activities	High (5.25)	Low (3.875)
Friendly activities	High (5)	Moderate (4.25)
General threat	Moderate (4.875)	Low (3.625)
Where I need to go	High (5.25)	High (5.125)

Rated spatial awareness

M5. Rate your spatial/navigational awareness (i.e. where you need to go and location of ownship in relation to enemies, friendly units, target and other relevant objects and landmarks in the environment) during **THIS** mission. Average scores; Low (1-3), moderate (4) and high (5-7)

Average rated spatial awareness overall; MS present 5.4, MS not present=4.5

	MS present	MS not present
Overall Spatial Orientation	High (5.625)	Moderate (4.875)
Ownship location in relation to objectives (e.g. bridge)	High (5.5)	Moderate (4.75)
Ownship location in relation to enemy activity	High (5.375)	Moderate (4.25)
Ownship location in relation to friendly activity	High (5.125)	Moderate (4.375)
Target location relative to enemy and friendly units	High (5.25)	Moderate (4.125)
Important landmarks	High (5.5)	Moderate (4.875)
General layout of the navigated area	High (5.75)	Moderate (4.875)
Information provided by the ERSTA system	High (5.125)	Low (3.875)

Rated crew activity

M6. Rate the following crew activity during **THIS** mission.
Average scores; low (1-3), moderate (4) and high (5-7)
Average rated crew activity; MS present=5.32, MS not present=2.446

	MS present	MS not pres
Overall **quality** of communication	High (5.125)	Moderate (4.125)
The **usefulness** of information provided by the Mission specialist	High (5.875)	.0000
Ability to **instruct** the Mission specialist	High (5.25)	.0000
Awareness of Mission specialist activity	High (5.375)	.0000
Ability to **convey** information to flying pilot	High (5.375)	Moderate (4.75)
Coordinating all tasks	High (5.25)	Moderate (4)
Coordinating communication	5.0000	4.2500

Rated Workload

M7. Rate your workload during **THIS** mission. Circle NA if not applicable for this mission.
Average scores; low (1-3), moderate (4) and high (5-7)
Average rated workload; MS present=3.10, MS not present= 3.35

	MS Present	MS not present
Communicating with flying pilot	Low (3)	Moderate (4)
Communicating with the Mission specialist	Low (3.0833)	.5000
Navigating	Moderate (4)	Moderate (4.25)
Maintaining/following the route	Low (3.8333)	Low (3.5833)
Finding waypoints	Low (3.5)	Low (3.3333)
Guiding the flying pilot to position the aircraft in the recce zone	Low (3.9167)	Moderate (4.4167)
Guiding the Mission specialist to position the sensor	Low (2.75)	.5000
Positioning the sensor	Low (2)	Low (5.5000)
Operating CDU	.0000	.0000
Radio communications	Low (2.75)	Moderate (4.6364)
Monitoring friendly activity	Low (2.75)	Low (3.3333)
Monitoring enemy activity	Moderate (4.1667)	Moderate (4.75)
Monitoring general threats	Moderate (4)	Moderate (4.4167)
Ingress to first waypoint	Low (2.6667)	Low (2.4167)
First waypoint to release point (RP)	Low (2.75)	Low (2.75)
Recce zone [release point to target]	Moderate (4.0833)	Moderate (4.2727)
Egress [target to end]	Low (2.75)	Low (3)
Overall	Low (3.9167)	Moderate (4.75)

Open-ended questions

1. When there was **no** Mission Specialist present, would you see value in having a Mission specialist? **YES or NO.** Please elaborate:

P1: (MS not present) Yes. Are you kidding? First of all, he is qualified recce. Second, he had experience with ERSTA. Third, he has control I do not have up front. Finally, it would reduce the MC's workload.
P2: (MS not present) Yes. A lot less workload for me. MS can do communications, operate sensors and help me evaluate best course of action.
P3: (MS not present) Yes. Absolutely!! MC was in "overload" mode for most of the recce area operations trying to both give directions to the FP plus operating the sensor. Adding communications with outside agencies made the work flow even busier. MC was too involved in detailed operation of sensor to achieve good overall SA.
P4: (MS not present) Yes. Absolutely. Without the MS, I felt task saturated—much more busy, the quality of the mission (i.e., the ability to gather information) was significantly reduced. Frustration levels would be less and communication would be enhanced with the addition of a MS.
P5: (MS not present) Yes. Only a slight increase in enemy contact would have overloaded MC task load.
P6: (MS not present) Yes. This would greatly decrease the workload. The need to decrease the workload on the MC was required in this mission.
P7: (MS not present) Yes. I could have spent more time focusing on the big picture while the MS could have put the sensor to better use.
P8: (MS not present) Yes. It is easier to supervise, direct and follow the mission. When I was absorbed by the sensor I did not notice the aircraft had turned and we were exposing the side of the aircraft, which made us more visible to the enemy.

2. When there **was** a Mission Specialist present would you see value in not having a Mission specialist? **YES or NO**. Please elaborate:

P1: (MS present) No. The MS is much more aware of what is going on. He has key personnel (qualified crew) using them to his advantage and thus he (MC) has much more time to control everything.
P2: (MS present) No. It is very hard to navigate and operate ERSTA at the same time. Especially if you have a second a/c to control
P3: (MS present) No.
P4: (MS present) No. The MS's contribution to the mission was instrumental to its success.
P4: (MS not present) No.
P5: (MS present) No. My workload would have doubled.
P6: (MS present) No. The workload reduced by having an MS. Greatly improved the ability to complete the mission within the time frame allocated.
P7: (MS present) No. The MS was able to conduct many of the tasks while MC could focus on the larger picture.

P8: (MS present) No. It decreases the workload by having someone taking care of some of the radio transmissions. Using the sensor would keep me from looking outside and at the map. Having a MS I can only glance at the image without having to adjust it.
P8: (MS not present) No.

3. Would it be beneficial to have a Mission Commander override for the ERSTA system? **YES or NO**. Please elaborate:

P1: (MS present) No. Unless there is a problem with the system (i.e., with the controls in the back).
P2: (MS present) No. But as MC, I could give the MS the word of command to let me have control of the system or guide him on the target I want to see.
P2: (MS not present) No. But as MC, I could give the MS the word of command to let me have control of the system or guide him on the target I want to see.
P3: (MS present) Yes. At certain times this may be necessary but for the majority of the time the MS operated the senor and provided the necessary input.
P4: (MS present) Yes. If the MS became incapacitated due to any reason then the MC should be able to use the system.
P4: (MS not present) Yes. If the mission specialist was incapable of performing the required task it could be then handed over to the MC.
P5: (MS present) Yes. Only when required for short duration to orient sensor operator to MC desired area of observation.
P6: (MS present) Yes. It would be required by the MC to have the ability to redirect the MS by physically moving the sensor. The MC could also take control to view an area of concern.
P7: (MS present) No. It was easy to redirect the MS onto areas of interest.
P8: (MS present) Yes. If after trying to explain to the MS where to look with the sensor without success, then having an override could cut down time spent trying to direct someone to direct the sensor. Keep in mind that the MS frustration level could go up slightly.
P8: (MS not present) Yes.

4. Was there a time when you needed to, but could not operate the sensor (e.g. the Mission specialist had locked the system**) YES or NO** Please elaborate:

P1: (MS not present) Yes. To lock the camera on the AC’s heading would have facilitated my job. It is not realistic to operate this way because mission accomplishment would have very low chance of completion.
P1: (MS not present) Yes. Trying to align the camera toward the targets.
P2: (MS present) No.
P3: (MS present) No.
P4: (MS present) No. At no point did I feel it necessary to take control of the sensor. The MS was doing a great job and I was able to focus on other aspects of the mission.
P4: (MS not present) No.
P5: (MS present) No.
P6: (MS present) No. It was easy to communicate between the MC and MS to determine who was in control of the asset.

P7: (MS present) No. I did not feel the need to operate the sensor.
P8: (MS present) No. I did not need to use it. It was pointed exactly where I wanted it.

5. At any point, did you find that your workload was very different (e.g., much higher or lower) than across the mission as a whole? **YES or NO** If yes, please elaborate:

P1: (MS not present) Yes, doing contact report, calling artillery onto enemy positions and trying to align camera while zooming in.
P1: (MS present) Yes. Much lower workload due to excellent work done by mission specialist
P2: (MS present) Yes. Giving direction to the pilot when in or close to an observing position.
P2: (MS not present) Yes. The workload is a lot more when in contact with the enemy.
P3: (MS present) Yes. During the first NOE , tactical movement from release point to first area of observation. Some of this was due to limited familiarity with both the aircraft and sensor systems. Also, first time working as a crew so developing out CRM and interpersonal interactions.
P3: (MS not present) Yes. Workload while observing target area, engaging with artillery and give SITREPs was intense.
P4: (MS present) Yes. In the observation point when we had eyes on the objective there was more radio communication and the helicopter required a bit more manoeuvering to get into position thus more coordination was required on my behalf.
P4: (MS not present) Yes. Within the recce zone—the workload significantly increased (more communications, more manipulation of the sensor, more manoeuvering and hence navigation to get into a good location to observe the object).
P5: (MS present) Yes. When the FP identified artillery impact in vicinity of OP3.
P5: (MS not present) Yes. Once enemy contact was achieved, I had higher workload (maintaining contact to the task list, navigating, communicating, etc.).
P6: (MS present) Yes. The requirement to reposition the helicopter to better utilize the ERSTA required an increased workload. At this point, the MC had to redirect the MS search area, find a new observation point and direct the flying pilot to the new observation point.
P6: (MS not present) Yes. At the recce zone. Just too many things to do. Any interruption or break in flow would overload the MC.
P7: (MS present) Yes. In the recce area there were more tasks to complete and maintain SA.
P7: (MS not present) Yes. With additional sensor duties, from release point to egress workload was higher causing me to work harder. However, overall wit this higher workload, I felt I performed better than in the run with a MS although the full utilization of the sensor's capabilities suffered.
P8: (MS present) Yes. Slightly higher after the release point until the end of the mission.
P8: (MS not present) Yes. Whenever I had to operate the sensor to find the target workload was higher. Once the sensor was on target, it was fairly easy to keep it on target.

6. If at any point you found that your workload was very different, what aspects of your tasks (e.g., radio communication, using information to control aircraft, flying aircraft, etc.) were affected?

P1: (MS present) Mission went extremely well.
P2: (MS present) When I had to give direction to flying pilot, when we had a target to engage.
P2: (MS not present) When the workload increased, I had a hard time keeping the flying pilot informed of tactical situation.
P3: (MS present) Using digital map and sensor system to guide aircraft (FP) and direct work of MS.
P3: (MS not present) While in situation stated above (observing target area, engaging with artillery and giving SITREPs), operation of the sensor was the most degraded.
P4: (MS present) I don't think anything was affected.
P4: (MS not present) Radio communications became more difficult and were lower on the priority list. Communication between the MC and FP became less clear and hence positioning the aircraft was more difficult.
P5: (MS present) All requirements became compressed into a 1-2 minute time period (navigating, avoiding enemy, communicating with crew).
P5: (MS not present) Monitoring of aircraft, instruments and other non-flying pilot duties suffered.
P6: (MS present) Radio communications and battlefield SA were affected the most.
P6: (MS not present) All tasks were affected. The need to divide my concentration between the tasks reduces the ability to effectively complete them.
P7: (MS present) Most radio communications were handled by the MS. There was less time available to direct flying pilot in recce zone.
P7: (MS not present) When doing radio communications, I felt I had a better idea of what was being transmitted. Guidance to FP suffered due to sensor operator duties.
P8: (MS present) None.
P8: (MS not present) Directing FP. Situation awareness: target clock angle in relation to aircraft.

TLX WORKLOAD ASSESSMENT

Instructions. Place an X on each scale at the point that represents the magnitude of each factor in the mission you just performed. Refer to the Workload Scale Descriptions for definitions of each factor.

SEGMENT OF MISSION: **Ingress to release point**

	MS present	MS not present
Mental demand	2.7500	2.6667
Physical demand	2.6250	2.5833
Temporal demand	2.9167	2.6667
Frustration level	2.4583	2.1667
Effort	2.6667	2.7083
Performance	8.5000	8.2500

SEGMENT OF MISSION: **Release point to first observation point**

	MS present	MS not present
Mental demand	4.4167	3.9167
Physical demand	3.0000	2.8333
Temporal demand	4.2500	4.3750
Frustration level	3.2083	3.6250
Effort	4.3750	4.5833
Performance	7.8333	7.6250

SEGMENT OF MISSION: **Getting and maintaining observation of target**

	MS present	MS not present
Mental demand	4.6250	5.5000
Physical demand	3.0417	3.7500
Temporal demand	4.7917	6.0000
Frustration level	4.1667	5.7083
Effort	4.9167	6.4583
Performance	7.7917	5.9583

SEGMENT OF MISSION: **Overall activity while in Recce zone.**

	MS present	MS not present
Mental demand	4.8750	5.7917
Physical demand	3.4167	4.0000
Temporal demand	4.5833	6.3333
Frustration level	4.0833	6.0000
Effort	5.3333	6.5000
Performance	8.2500	6.3750

SEGMENT OF MISSION: **Egress**

	MS present	Ms not present
Mental demand	3.0833	3.4583
Physical demand	2.5417	3.0000
Temporal demand	3.2083	3.3333
Frustration level	2.0417	2.5833
Effort	2.7500	3.2500
Performance	8.9583	8.3750

ANNEX F

Post-Mission Comparison Questionnaires

TAMSS Experiment 3

Participant ID:____________________

Day 1: Mission specialist present versus No Mission specialist present

FLYING PILOT VERSION

Rate the impact of having a Mission specialist present as compared to having no Mission specialist. A rating of '4' means there was no difference between a Mission specialist vs. no Mission specialist.

	COMPARISON						
	Mission specialist present			No difference			**No Mission specialist present**
1. Overall situation awareness	1	2	3	4	5	6	7
2. Overall mission awareness	1	2	3	4	5	6	7
3. Awareness of spatial orientation	1	2	3	4	5	6	7
4. Awareness of activities (enemies, friendly units)	1	2	3	4	5	6	7
5. Anticipating future events	1	2	3	4	5	6	7
6. Using information from the ERSTA system to control the aircraft	1	2	3	4	5	6	7
7. Awareness of heading	1	2	3	4	5	6	7
8. Communication to Mission Commander	1	2	3	4	5	6	7
9. Other radio communication	1	2	3	4	5	6	7
10. Low-level flight	1	2	3	4	5	6	7
11. Low-level maneuvering	1	2	3	4	5	6	7
12. Maintaining heading	1	2	3	4	5	6	7
13. Overall workload	1	2	3	4	5	6	7

TAMSS Experiment 3

Participant ID:____________________

Day 2: Mission specialist present versus No Mission specialist present

FLYING PILOT VERSION

Rate the impact of having a Mission specialist present as compared to having no Mission specialist. A rating of '4' means there was no difference between a Mission specialist vs. no Mission specialist.

	COMPARISON						
	Mission specialist present			No difference		**No Mission specialist present**	
1. Overall situation awareness	1	2	3	4	5	6	7
2. Overall mission awareness	1	2	3	4	5	6	7
3. Awareness of spatial orientation	1	2	3	4	5	6	7
4. Awareness of activities (enemies, friendly units)	1	2	3	4	5	6	7
5. Anticipating future events	1	2	3	4	5	6	7
6. Using information from the ERSTA system to control the aircraft	1	2	3	4	5	6	7
7. Awareness of heading	1	2	3	4	5	6	7
8. Communication from Mission Commander	1	2	3	4	5	6	7
9. Communication to Mission Commander	1	2	3	4	5	6	7
10. Other radio communication	1	2	3	4	5	6	7
11. Low-level flight	1	2	3	4	5	6	7
12. Low-level maneuvering	1	2	3	4	5	6	7
13. Maintaining heading	1	2	3	4	5	6	7
14. Overall workload	1	2	3	4	5	6	7

TAMSS Experiment 3

Participant ID: ____________________

Day 1: Mission specialist present versus no Mission specialist present

MISSION COMMANDER VERSION

Rate the impact of having a Mission Specialist present as compared to having no Mission Specialist on **YOUR performance and experiences as the MC** in the scenarios. Circle your response for each item. A rating of '4' means there was no difference between having a Mission Specialist vs. no Mission Specialist.

	COMPARISON						
	Mission specialist present			No difference		**No Mission specialist present**	
1. Overall situation awareness	1	2	3	4	5	6	7
2. Keeping track of activity (enemies, friendly units)	1	2	3	4	5	6	7
3. Overall spatial orientation	1	2	3	4	5	6	7
4. Using the map to navigate	1	2	3	4	5	6	7
5. Following the route	1	2	3	4	5	6	7
6. Reading the digital map	1	2	3	4	5	6	7
7. Using the CDU	1	2	3	4	5	6	7
8. Using comms	1	2	3	4	5	6	7
9. Communication to flying pilot	1	2	3	4	5	6	7
10. Communication from flying pilot	1	2	3	4	5	6	7
11. Using the sensor effectively	1	2	3	4	5	6	7
12. Submitting a contact report	1	2	3	4	5	6	7
13. Submitting a SITREP	1	2	3	4	5	6	7
14. Executing a Fire Support Mission (FSM)	1	2	3	4	5	6	7
15. Other radio communication	1	2	3	4	5	6	7
16. Eyes out time	1	2	3	4	5	6	7

17. Positioning the aircraft in the recce zone							
18. Overall usefulness of the information available from the ERSTA system	1	2	3	4	5	6	7
19. Overall mission awareness	1	2	3	4	5	6	7
20. Anticipating future events	1	2	3	4	5	6	7
21. Completing the mission	1	2	3	4	5	6	7
22. Overall workload	1	2	3	4	5	6	7

TAMSS Experiment 3

Participant ID: ____________________

Day 2: Mission specialist present versus no Mission specialist present

MISSION COMMANDER VERSION

Rate the impact of having a Mission Specialist present as compared to having no Mission Specialist on **YOUR performance and experiences as the MC** in the scenarios. Circle your response for each item. A rating of '4' means there was no difference between having a Mission Specialist vs. no Mission Specialist.

	COMPARISON						
	Mission specialist present			No difference		**No Mission specialist present**	
1. Overall situation awareness	1	2	3	4	5	6	7
2. Keeping track of activity (enemies, friendly units)	1	2	3	4	5	6	7
3. Overall spatial orientation	1	2	3	4	5	6	7
4. Using the map to navigate	1	2	3	4	5	6	7
5. Following the route	1	2	3	4	5	6	7
6. Reading the digital map	1	2	3	4	5	6	7
7. Using the CDU	1	2	3	4	5	6	7
8. Using comms	1	2	3	4	5	6	7
9. Communication to flying pilot	1	2	3	4	5	6	7
10. Communication from flying pilot	1	2	3	4	5	6	7
11. Using the sensor effectively	1	2	3	4	5	6	7
12. Submitting a contact report	1	2	3	4	5	6	7
13. Submitting a SITREP	1	2	3	4	5	6	7
14. Executing a Fire Support Mission (FSM)	1	2	3	4	5	6	7
15. Other radio communication	1	2	3	4	5	6	7
16. Eyes out time	1	2	3	4	5	6	7

17. Positioning the aircraft in the recce zone							
18. Overall usefulness of the information available from the ERSTA system	1	2	3	4	5	6	7
19. Overall mission awareness	1	2	3	4	5	6	7
20. Anticipating future events	1	2	3	4	5	6	7
21. Completing the mission	1	2	3	4	5	6	7
22. Overall workload	1	2	3	4	5	6	7

ANNEX G

Summary Data: Post-Mission Comparison Questionnaires

Summary of Final Questionnaire
TAMMS Project- Experiment 3

Flying Pilot Role

overall situation awareness	3.2857
overall mission awareness	3.7500
awareness of spatial orientation	3.6250
awareness of activities (enemies, friendly units)	2.8571
anticipating future events	3.3750
using information from the ERSTA system to control the aircraft	3.1250
awareness of heading	3.7500
communication from mission commander	3.5000
communication to mission commander	3.2500
other radio communication	2.7500
low-level flight	3.7500
low-level maneuvering	3.6250
maintaining heading	4.0000

1= Much better with Mission Specialist, 4=no difference, 7= much better with no Mission Specialist

Summary of Final Questionnaire
TAMMS Project- Experiment 3

Mission Commander Role

overall situation awareness	2.0000
keeping track of activity (enemies, friendly units)	1.8750
overall spatial orientation	3.1250
using the map to navigate	3.3750
following the route	3.5000
reading the digital map	3.6250
using the CDU	3.0000
using comms	2.6250
communication to flying pilot	2.6250
communication from flying pilot	3.0000
using the sensor effectively	1.5000
submitting a contract report	1.6250
submitting a SITREP	2.0000
executing a fire support mission (FSM)	1.6250
other radio communication	2.2500
eyes out time	2.2500
positioning the aircraft in the recce zone	2.7500
overall usefulness of the information available from the ERSTA system	1.7500
overall mission awareness	1.8750
anticipating future events	2.5000
completing the mission	2.0000
overall workload	2.5000

1= Much better with Mission Specialist, 4=no difference, 7= much better with no Mission Specialist

List of symbols/abbreviations/acronyms/initialisms

3D	3 Dimensional
API	Application Programming Interface
ASCII	American Standard Code for Information Interchange
CACR	Centre for Applied Cognitive Research
CDTV	Colour Day Television
CDU	Control Display Unit
CMC	Canadian Marconi Company
COTS	Commercial Off-the-Shelf
CPT	Cockpit Procedures Trainer
CRM	Crew Resource Management
CSC	Communication Selection Control
CSE	Cognitive Systems Engineering
DACS	Digital Audio Communication System
DND	Department of National Defence
DRDC	Defence Research & Development Canada
EOS	Experimenter Operating Station
ERSTA	Electro-optical Reconnaissance, Surveillance and Target Acquisition
FOM	Federation Object Model
FOV	Field-of-View
FMFS	Full Motion Flight Simulator
FP	Flying Pilot
GUI	Graphical User Interface
HDD	Head-Down Display

HLA	High Level Architecture
HMD	Helmet Mounted Display
HUD	Head-Up Display
IG	Image Generator
IP	Internet Protocol
ISTS	Integration Simulation Training System
LAN	Local Area Network
LATEF	Land Aviation Tactical Evaluation Flight
LCD	Liquid Crystal Display
M&S	Modelling & Simulation
MC	Mission Commander
MS	Mission Specialist
MTBF	Mean Time Between Failures
NASA	National Aeronautics and Space Administration
NFP	Non-Flying Pilot
NTS	Networked Tactical Simulator
NVG	Night Vision Goggles
ODBC	Open Database Connectivity
OTW	Out-the-Window
PC	Personal Computer
PTT	Part-Task Trainer
RMS	Root Mean Square
RPR	Real-time Platform Reference
RTOS	Real Time Operating System

SA	Situational Awareness
SBE	Simulation Based Evaluation
SME	Subject Matter Expert
SQL	Structured Query Language
TAMSS	Tactical Aviation Mission Systems Simulations
TLX	Task Load Index
TT	Tactics Trainer
UDP	Unicast Datagram Packet
WAN	Wide Area Network

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(U) This document reports on the Department of National Defence (DND) Tactical Aviation Mission System Simulation (TAMSS) Situation Awareness (SA) project. The TAMSS SA project was conducted at the Centre for Applied Cognitive Research (CACR) at the Carleton University. In accord with the original goals of this project, the deliverables included the development of a CH146 Griffon simulation capability at the CACR, the development of a theoretical framework to guide the evaluation process, three experiments that both assessed an engineering system and a theoretical framework, and this document, which summarizes the TAMSS SA project and provides a link to acquisition programs and to potential simulation−based training applications. The TAMSS SA project provides a guide for the implementation of simulation−based evaluation on a cost−effective platform. The combination of the CSE framework and the research−enabling simulation environment that was developed in the TAMSS SA project can be used to reduce risk and enhance value in acquisition programs. Collaboration among the Carleton University CACR researchers, including graduate students, and from the visits from many DND personnel, subject matter experts, and industry representatives, has demonstrated the value of locating these activities in a research−rich environment.

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(U) TAMSS
Simulation
Distributed simulation
HLA (High Level Architecture)
Situation awareness
CH146
Griffon