A LOW-COST COCKPIT FAMILIARISATION TRAINER FOR THE EH101 HELICOPTER

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INTRODUCTION

The Customer Training Centre at GKN Westland Helicopters required a training device to teach basic cockpit orientation and procedures training for the EH101 helicopter, Figure 1.

Figure 1 - The EH101 Helicopter

The target trainee population includes both pilots and maintainers. They are generally experienced in older-generation helicopters. The main new technology they will encounter in the EH101 cockpit includes:

- An Electronic Instrument System (EIS or "glass cockpit") with multiple page formats.
- Presentation on the EIS of advisories, cautions, and (flight-card) check lists.
- Simpler engine management because of Full Authority Digital Engine Control (FADEC).
- A computerised Aircraft Management System (AMS) with extensive Health and Usage Monitoring System (HUMS) capabilities.

A physical three-dimensional replica cockpit was available when an engineering rig (for the evaluation of cockpit lighting) completed development tests. Figure 2 is a photograph of the exterior of the lighting rig. The interior of the lighting rig contained the basic cockpit structure, but the majority of the cockpit panels, controls and displayed had been removed.

Figure 2 - Exterior of Disused Lighting Rig

The Customer Training Centre's original intention was to acquire the lighting rig and to refurbish it into a static high-fidelity but *non-interactive* cockpit mock-up. Several competitive costings were obtained, but all exceeded the limited budget allocated to this project, primarily because of the high-cost of aircraft switches and indicators.

This paper presents an innovative solution, which not only met the budget, but also provided extensive interactive feedback (visual and audio cues) in response to cockpit actions.

Before we present the system architecture for the low-cost solution adopted, we will review the training objectives, and instructional strategies for learning cockpit skills.

TRAINING OBJECTIVES

The Systems Approach to Training (SAT) [References 1 to 6, inclusive] provides a closed-loop iterative approach to the Analysis, Design, Conduct and Evaluation of Instructional Systems (Figure 3).

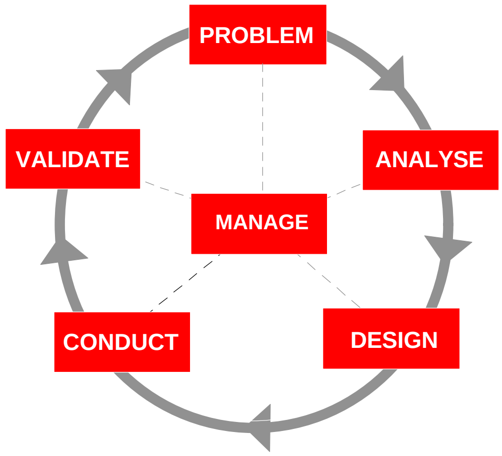

Figure 3 - The Systems Approach to Training

Training Objectives for the CFT, developed in accordance with the analysis phase of SAT, focus on the identification and location of cockpit controls, switches and indications, and the performance of normal and emergency cockpit drills.

For aircrew, the Training Objectives (performance statement only) allocated for the EH101 CFT are:

1. Identify cockpit controls, switches and indicators.
2. Locate cockpit controls, switches and indicators.
3. Practice the following crew operating procedures in the cockpit, in accordance with the flight reference cards:
   - Pre-engine-start checks.
   - After-engine-start checks.
   - Pre-taxi checks.
   - Pre-takeoff checks.
   - After takeoff checks.
   - Periodic en-route checks.
   - Pre-landing checks.
   - After-landing checks.
   - Engine shut down checks.
   - Additional operational procedures.
4. Practice the following emergency cockpit procedures in accordance with the relevant flight reference cards:
   - Engine malfunction and shutdown.
   - Engine fire.

For maintainers, Training Objectives (performance statements) allocated for the EH101 CFT include:

1. Identify cockpit controls, switches and indicators.
2. Locate cockpit controls, switches and indicators.
3. Practice the operation and control of EH101 avionic and mechanical systems.

REQUIRED CUES

While a static high-fidelity cockpit mock-up (replica panels laid out in the correct three-dimensional relationship) provides the required visual and tactile cues for the identification and location of cockpit controls and displays, it does not provide any of the important feedback which is necessary to progress beyond this point.

The EH101 cockpit provides important cues on the Electronic Instruments (Figures 6, 7, 8, 9). Colour and animation are highly desirable to portray the run-up/down of engine parameters in digital and bar-graph format. Audio cues also provide vital cues such as advisories, cautions and warnings.

While conventional CBT can provide these visual and audio cues in isolation, CBT cannot also provide the required tactile cues in a three-dimensional environment.

INSTRUCTIONAL STRATEGY

Williams [Reference 7] reviews pilot training, and suggests a strategy for effective learning of cockpit drills. He argues that learning of each performance element involves cycles of Action, Reaction, Integration and Generalisation (Figure 4), and that retention and transfer of learning are increased if classroom training and practical skills training are integrated.

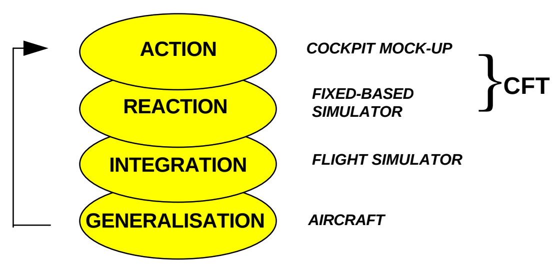

Figure 4 - Williams' Concept for Aircrew Training

In the Action phase of training, students learn two things. Firstly, they learn the actions they must perform to complete a job performance component, for example, to start the engines. Concurrently they learn knowledge about what happens in the aircraft systems affected by their actions.

Williams considers that Action training should be conducted in a full-scale non-interactive cockpit mock-up. He invokes a simple trainer in which the students provide the completion cues themselves. To achieve concurrent learning about the aircraft systems, he proposes that CBT should be available at the Action trainer to show the students what happens in a particular aircraft systems. This capability to practice aircrew checklists with concurrent review of related CBT material about aircraft systems is a key requirement in the concept for the EH101 CFT.

The key element of a Reaction trainer is to supply the completion cues (in real-time) to each student action. In the Reaction phase, the student crew continues to integrate knowledge and skills by practising check lists in phase-of-flight order. Another important element in the concept for a Reaction training device is to demand 100% proficiency: all the correct steps (in the right order) must be performed within a given time limit. An example of a Reaction training device is an FAA-defined Level 6 flight training device. This is an aircraft-specific fixed-based simulator, i.e. without a motion base or visual system.

The remaining phases of learning are Integration and Generalisation. Integration takes place on a full-flight simulator, where the robustness of the crew's performance is increased under conditions of additional stimulation from motion and out-the-window visual cues. Generalisation training takes place in the aircraft - crews develop confidence in their training by observing repeatedly how their skills and knowledge can be generalised across a wide range of actual conditions.

CONCEPT FOR THE EH101 CFT

The concept for the EH101 CFT achieves the 3-D cockpit familiarisation of the Action training device, with capabilities for concurrent review of classroom CBT courseware. The CFT also achieves the functionality of the Reaction training device, but with a capital cost of around £200k - an order of magnitude (ten times) lower than a conventional fixed-base or flight simulator (around £2M). The key features of the EH101 CFT are:

1. It provides trainees with EH101 familiarisation via a high-fidelity 3-D dimensional physical cockpit environment. Cockpit controls and indicators are reproduced with high-fidelity. The overhead panel, instrument panel and inter-seat panel are reproduced to the latest aircraft standard. Two aircraft seats and seat rails are incorporated.

2. All cockpit controls and indicators required for cue and response requirements are interfaced to the computer system.

3. The CFT allows trainees to practice procedural scenarios which cover the flight reference card drills for both normal and emergency procedures. The drills span all phases of flight from pre-flight to post-landing engine shut down.

4. The Electronic Instrument System displays are replicated using commercial monitors. Animated EIS images are presented on these displays in concert with the procedural scenarios.

5. An intercom for the crew and instructor is included. Audio cues associated with advisories, cautions, and warnings are injected, together with the audio from the independent CBT system.

6. Procedural scenarios, constructed using a CBT authoring system, permit correct sequences but display remediation messages if incorrect steps are initiated.

7. Concurrent to CFT activities, trainees can review Computer-Based Training (CBT) courseware about aircraft systems while sitting in the cockpit environment. The CBT images are presented on a large monitor positioned in front of the cockpit, and viewed through the cockpit window.

8. The CFT system architecture is based on personal computer technology.

9. Daily readiness functions (lamps test and switch test) are incorporated.

10. The CFT has provision for expansion to include additional procedures, and (ultimately) a flight model and simple control loading.

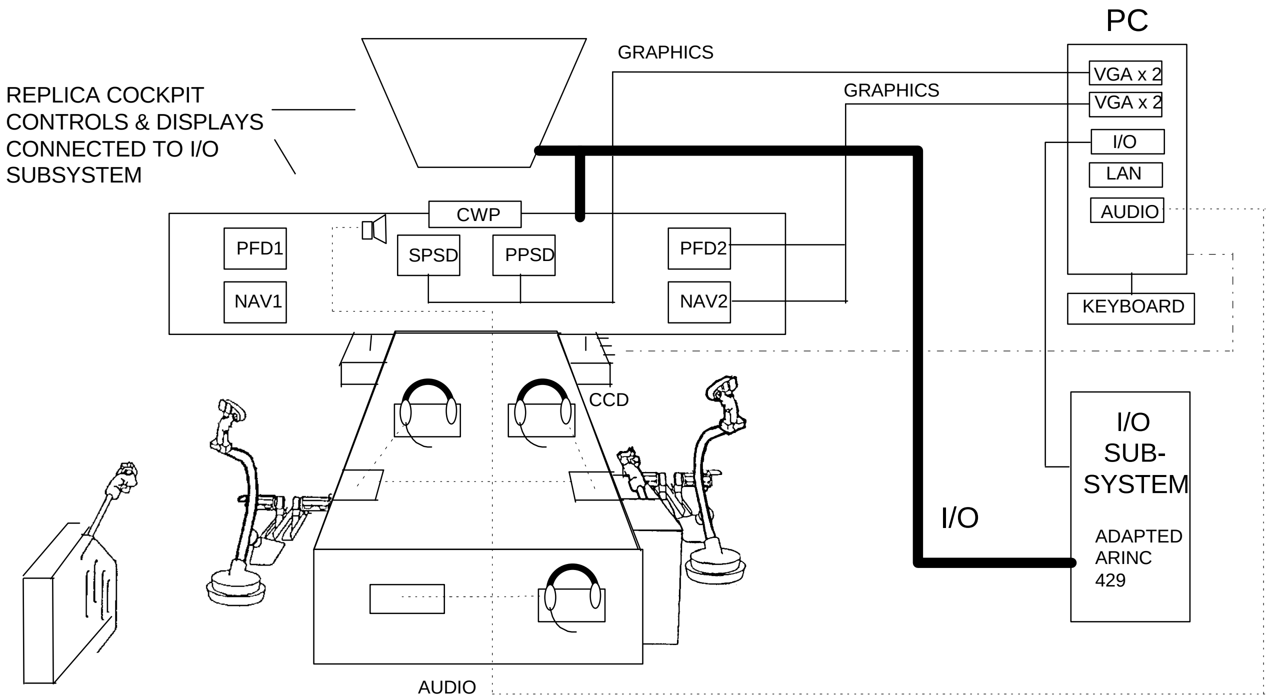

Figure 5 - System Architecture of the CFT

SYSTEM ARCHITECTURE

Figure 5 is a system architectural block diagram of the CFT (excluding the separate CBT computer system). The CFT uses personal computer technology.

All the replica cockpit panels, such as the Central Warning Panel (CWP) are interfaced to a Pentium™ personal computer via an Input/Output (I/O) sub-system. The I/O system uses a serial protocol (based on ARINC 429).

Four commercial 9" monitors (usually used for cash register applications) were repackaged to simulate four EIS "glass" cockpit displays. The EIS channels simulated are: The pilot's (right side) Primary Flight Display (PFD2), Navigation Display (NAV2), and the (central) Primary and Secondary Power Systems Displays (PPSD and SPSD). Simulated PFD and NAV displays are illustrated in Figure 6 and 7. The PFD and NAV display various modes which provide important cues including attitude, height, heading, airspeed, vertical speed, etc.

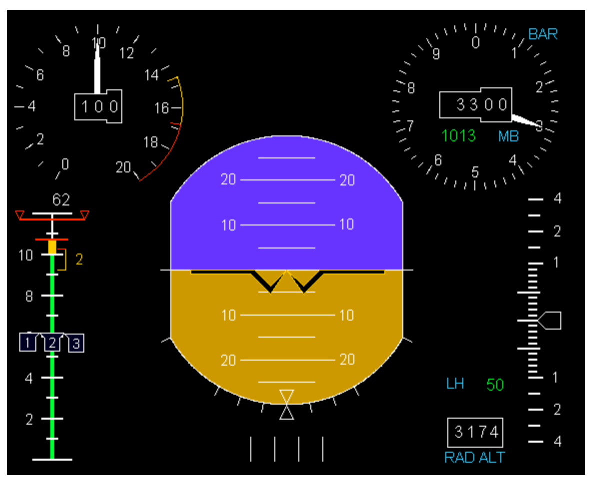

Figure 6 - Simulated PFD

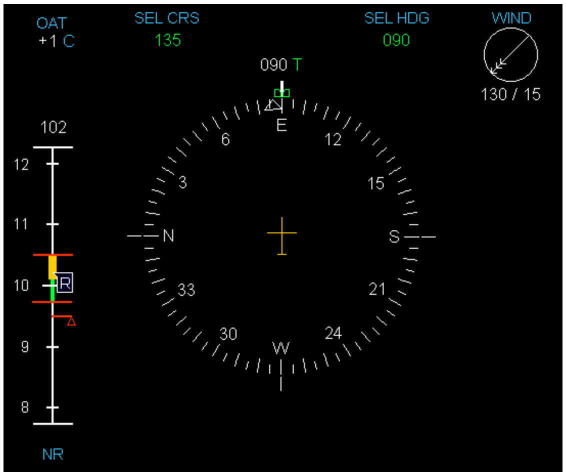

Figure 7 - Simulated NAV

The PPSD displays engine, fuel, electrical, and hydraulic status - important cues during start-up and shutdown. Relevant pages automatically appear in the case of aircraft system malfunctions in flight (such as engine failure). The SPSD is normally used to display advisories and cautions. Simulated SPSD and PPSD displays during engine start are shown in Figures 8 and 9.

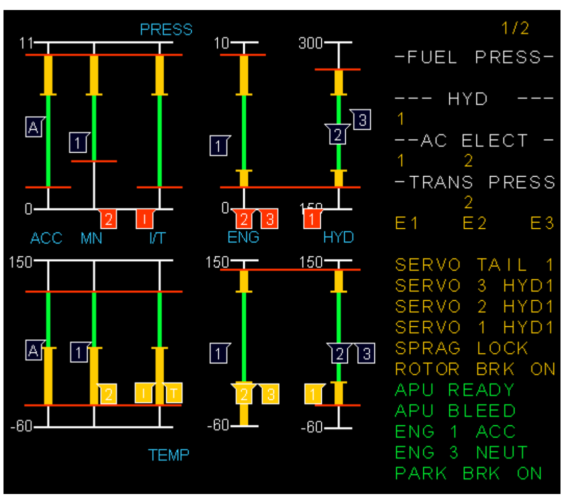

Figure 8 - Simulated SPSD

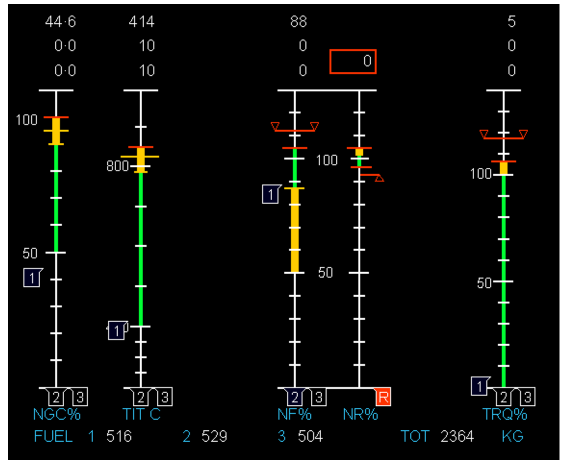

Figure 9 - Simulated PPSD

Two dual-screen VGA graphics cards create a single virtual screen in the Windows™ environment for the EIS displays. One dual-channel VGA card drives the PFD2 and NAV2, and the other drives PPSD and SPSD.

The computer system contains a digital audio board which will playback audio sounds into the two intercom station boxes and into a trainer-specific third intercom unit which can be used by an instructor or observer. A loudspeaker will also be fed with the audio signals.

Replicas of the cyclic, and collective sticks together with the yaw pedals are included for both the pilot and co-pilot. The sticks include physical replicas of all the controls and switches. Selected switches on the sticks are functional and are interfaced via the I/O system to the scenarios.

THE TRAINING SCENARIOS

Procedural scenarios were created using a CBT authoring system (Authorware). The scenarios interface via a Windows DDE to the I/O system which, in turn, interfaces with the switches and indicators in the replica panels.

Each scenario tracks the flight-card checklist. If the correct input has been made, the appropriate cockpit indications are displayed (including indicators, lamps, animated graphics on the four EIS channels) and appropriate audio cues (cautions, warning etc.) are generated.

The drills span all phases of flight. The following table is a list of the scenarios available on the CFT:

CFT Ref	Exercise Description	Flight Card
D1	Internal Checks	W8
D3	Pre APU Starting	W10
D4	APU Starting	W12
D6	Blade/Tail Spreading	W52
D5	Engine Starting	W20
D9	Pre Taxi Checks	W29
D10	Pre Take Off Checks	W31
D11	After Take Off Checks	W32
D12	Pre Landing Checks	W33
D13	After Landing Checks	W34
D15	Shutdown	W34
D14	Blade/Tail Folding	W53
D17	Engine Shutdown in Cruise	W44
D18	Engine Restart in Cruise	W45
D21	Manual Fuel Transfer	W49
D23	Single Engine Failure	R6
D24	Double Engine Failure	R8
D25	Engine Oil Pressure Low	R12
D26	Loss of Engine Control	R11
D27	Engine Bay Fire in Flight	R14
D28	Engine Bay Fire on the Ground	R13
D29	APU Fire in Flight	R16
D30	APU Fire on the Ground	R15
D31	Post Shutdown Fire in Exhaust	R17
D32	Main Gearbox Oil Pressure Low	R22
D33	Main Gearbox Oil Temperature High	R23
D34	Rotor De-Icing	R26
D35	Double AC Generator Failure	R29
LT	Lamps Test	N/A
SW	Switch Test	N/A

MENU SELECTION

Menu selection is performed using a Cursor Control Device (CCD, Figure 5) on the aircraft's mission system, whereupon trainer-specific menus (Figure 10) appear on the PFD. The concept adopted is to keep the cockpit as close to the aircraft as possible; there is no separate instructor control station.

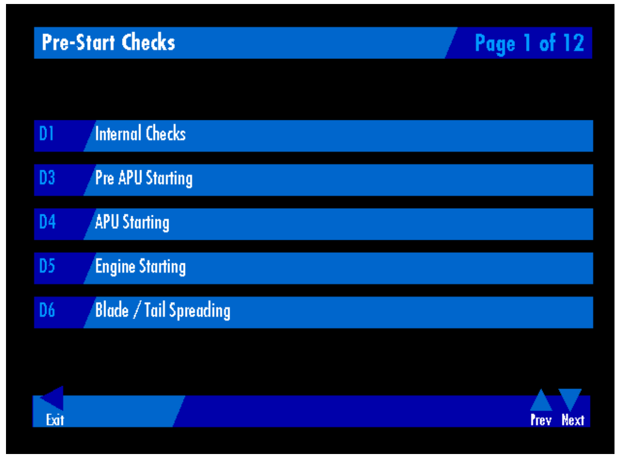

Figure 10 - Scenario Selection Menu on PFD

As an example, let us assume that the 'Engine Starting' scenario (D5) has been selected.

INITIALISATION

It is first necessary to ensure that the switches are in the correct position for the start of the scenario. In this example, the APU is already running and the electrical power is available on all busbars. A trainer specific screen appears to prompt the user to reset any out-of-position switches to the correct initial state for the new scenario, as illustrated in Figure 11. Yellow highlighting is used to indicate which switch is out of position. After one panel is reset, the computer prompts for the next panel requiring a switch to be reset, and so on until all panels are reset. Useability tests have shown that this interface is intuitive, quick and easy.

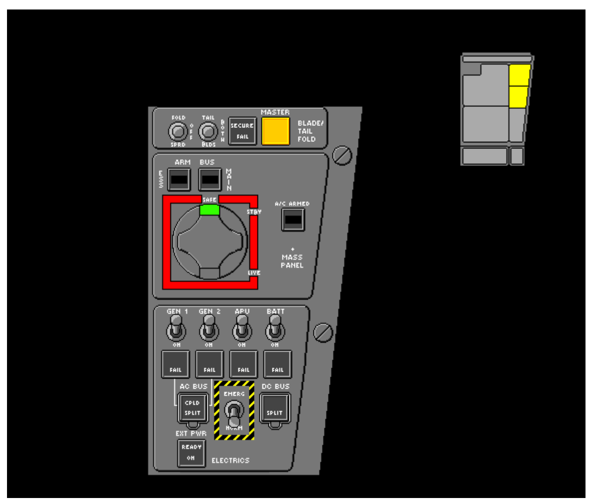
Figure 11 - Prompt for Out of Position Switch

When all resets are complete the trainer-specific prompts disappear from the PFD, the appropriate cockpit indications are displayed, and the training scenario is ready to commence.

PRACTICE SEQUENCE

The scenarios are designed so that the crew can practice performing the checks using the flight reference cards, exactly as would be done in the aircraft. For example, the first two steps of starting the number one engine are as follows:

1. *Action*: On the FUEL panel, select ENG 1 FUEL switch to ON.

- *Reaction*: The ENG 1 FUEL indicator switches from OFF to a cross-hatched (transition) state for one second, then goes to ON.

2. *Action*: On the Engine Control (FADEC) Panel of the overhead console, move the No. 1 engine CONDITION switch to GI (Ground Idle).

- *Reaction:* The number one engine starts. On the PPSD (Figure 9), the No. 1 engine bug changes to magenta, the Turbine Inlet Temperature increases, and the Engine Fan Revolutions increase. The SPSD (Figure 8) simultaneously shows the hydraulics pressurisation sequence, and various advisories. TRQ1 is repeated on the PFD (Figure 6), and NF1 is repeated on the NAV display (Figure 7). Etc.

There are 84 inputs (steps) required to start and check all three engines and their associated aircraft systems (fuel, hydraulics, electrics). Branching within the scenarios allows for the three engines of the EH101 to be started in two approved sequences - without pre-selection of the order at the main menu.

The data used for the detailed reproduction of the EIS animations during engine start have been obtained from aircraft documentation, flight trials videos, and discussions with the test pilots. Storyboards showing such cockpit indications at each step were approved by the pilots before implementation.

INCORRECT SEQUENCE

If the trainee positions a switch incorrectly, or out of sequence, a message "Incorrect step" appears in yellow on the PFD (Figure 12).

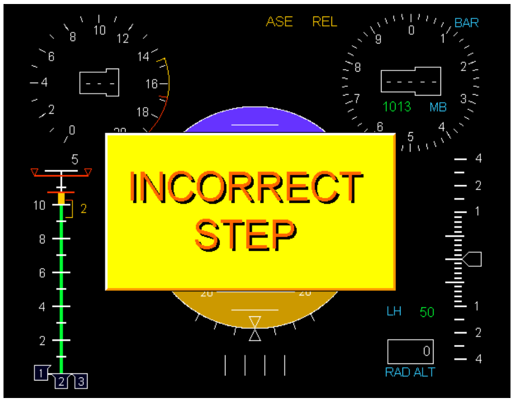

Figure 12 - Remediation Message on PFD

If the trainee does not immediately rectify the mistake, remediation appears on the PFD; this takes the form of a graphic, in the same style used for initialisation - as illustrated in Figure 11. This advises the action required to resume the correct sequence. This is an efficient way of providing positive reinforcement to achieve learning.

TIMING AND EXIT FROM SCENARIOS

The majority of scenarios also have built in timers at critical points. For example, after starting the Auxiliary Power Unit (APU), the trainees must wait 25 seconds for the APU to run up before generator can be selected on-line. In other instances, the trainees must complete cockpit actions within a defined given time limit. In both instances, a remedial message followed by a demonstration to rectify the incorrect step is presented to the trainees.

A discretely located trainer-specific button at the Cursor Control Device allows immediate exit from any scenario, and returns to the main menu, from which the next practice scenario can be selected.

PROFICIENCY ASSESSMENT

The CFT lends itself very well to the assessment of the proficiency of performing cockpit checklist. At first, new crew will be slow and will make mistakes. As they learn, proficiency can be assessed by the time taken to perform each particular scenario, as compared to a maximum allotted time. The overall time to complete each scenario can be monitored and displayed. This adds an element of competition between trainees, which is very useful to engender rapid learning!

ABILITY TO RUN CBT COURSEWARE

As discussed, it is highly desirable to review tutorials on how the aircraft systems operate as cockpit drills are being learnt. It is also an advantage to present such information in a cockpit setting where appropriate cockpit controls and displays are readily available. Typical CBT screens from the CBT courseware describing operation of the fuel system are illustrated in Figures 13 and 14.

It was decided to keep the cockpit exactly as the aircraft, without intrusive monitors. The solution was to mount a 17" monitor outside the front cockpit windows on an adjustable stand. Cursor selection is provided from within the cockpit. Human factors tests proved that this interface worked well.

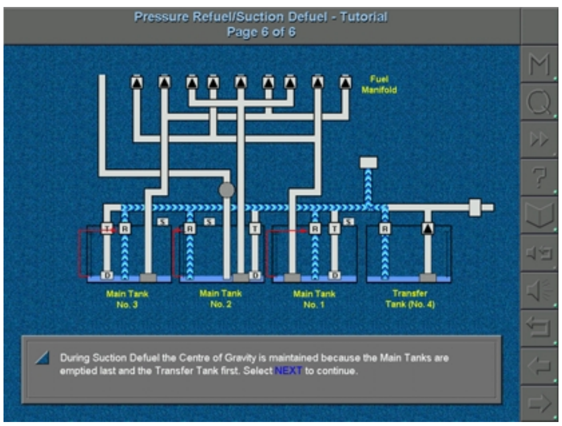

Figure 13 - Fuel System Schematic.

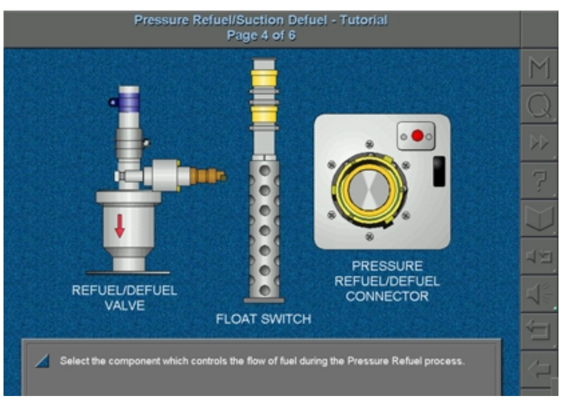

Figure 14 - Fuel System Components.

OPERATION AND MAINTENANCE

A single master power switch is used to turn on the trainer. This automatically boots both the CFT and CBT computer system. Use of keyboards is not necessary, other than for computer maintenance.

Daily readiness is achieved via a 'Lamps Test' and a 'Switch Test' option at the main menu. The lamps test displays a graphical image (Figure 15) of the cockpit on the PFD. Positioning the cursor and clicking the required panel turns on all the lamps within that panel. In the case of specialised electro-mechanical indicators (such as for the fuel shut-off valves) repeated selection exercises each of the positions (OPEN, SHUT, and cross-hatched for in-transit).

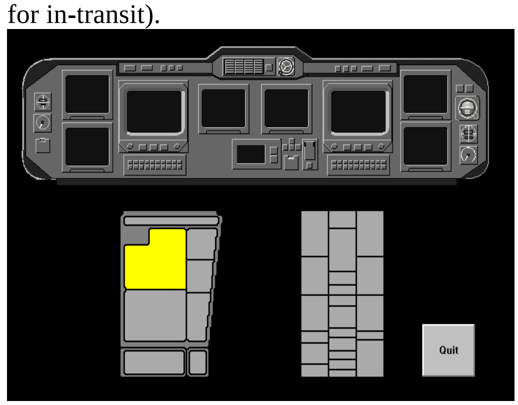

Figure 15 - Lamps Test Screen

The Switch Test option (Figure 16) displays a graphical image of all cockpit areas. The panel selected for testing is displayed as a detailed graphic showing all the switches that are interfaced to the computer system highlighted in yellow. Exercising these cockpit switches through all valid positions is required before the highlight is removed.

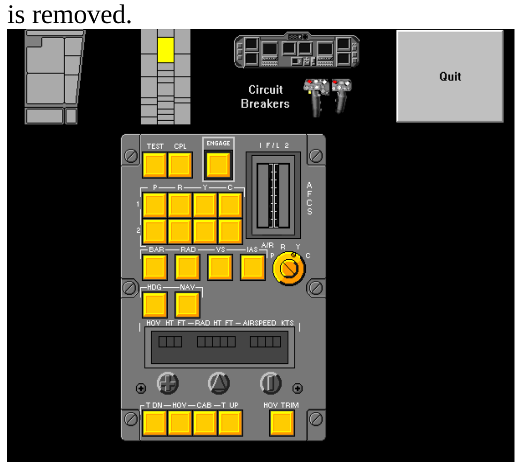

Figure 16 - Switch Test Screen

DEVELOPMENT & UTILISATION

The development of the EH101 was done in close co-operation with the Customer Training Centre. The major advantage of this co-operation has been the availability of data and subject-matter expertise. The Customer Training Centre also arranged reviews of each of the scenarios with the EH101 test pilots. These reviews have been invaluable in ensuring that the operation of the CFT matches the latest aircraft standard.

At the time of writing this paper, the EH101 CFT is about to complete acceptance tests and enter service. Other than the CBT courseware, the CFT will be the first dedicated EH101 training device to enter service. The Customer Training Centre intends to use the CFT as part of the forthcoming training courses for both aircrew and maintainers.

CONCLUSIONS

This paper has described a low-cost approach to cockpit familiarisation training in which conventional CBT courseware on a personal computer has been extended with replica cockpit controls and displays to create a high-fidelity physical cockpit environment.

The resultant Cockpit Familiarisation Trainer (CFT) provides the 3-D environment which satisfies all the visual and tactile cues required for the identification and location of cockpit panels, switches and indicators. By extending CBT procedural training scenarios to interface with the cockpit panels and displays, correct student actions can be monitored and appropriate system reaction can be provided. Such system reaction provides the essential completion cues (four-channel animated graphics for the Electronic Instrument System, cockpit indications, audio cautions and warnings) which allows students to learn cockpit drills on the ground and throughout all phases of flight. Practice to proficiency can be achieved. Such practice would otherwise only be achievable in more sophisticated fixed-based or flight simulators, with much larger capital and running costs.

The ability to view conventional CBT courseware while sitting in the cockpit environment increases the usefulness of the CFT. Such courseware illustrates the schematics and components of each aircraft system, and describes how each system operates. Viewing such CBT while in the cockpit environment allows knowledge and skills to be blended and theory and practice to be integrated. Such an approach increases retention and promotes learning transfer.

ACKNOWLEDGEMENTS

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