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SIMULATING GLASS COCKPIT DISPLAYS IN A GENERAL AVIATION FLIGHT ENVIRONMENT

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Development of a research platform that replicates the basic flight functions of a light, general aviation aircraft is described. This involved retrofitting an actual aircraft cockpit with computer displays to emulate an aircraft environment. The hardware and software used in this research platform are described, as well as issues and problems regarding implementation and use in research.

Introduction

Progress in computer and electronic technology has dramatically impacted the capabilities and design of modern avionics. The cockpits of most commercial and military aircraft of today bear little resemblance to those of 30 years ago. Recent advances in avionics have embraced the concept of combining the equipment, functions, and displays from various flight information and navigation systems into one or two highly integrated units. Large commercial and military aircraft have evolved in their use of electronic and computer technologies to the point where most modern aircraft utilize Electronic Flight Instrument Systems (EFIS), commonly referred to as "glass cockpit" technology. The electronic display units of glass cockpits are flexible and can present a vast array of information in different ways over which the pilot has control (Billings, 1997). Because these electronic displays are more user-friendly than traditional cockpit displays, the switch to EFIS has improved system reliability and safety.

This transition to EFIS has not been without its drawbacks, however. Analysis of recent airline accidents has demonstrated that there are many human factors involved in transitioning to and using such display technology (e.g., Kaber, Riley, & Tan, 2002). The pilot's mental workload may be reduced during routine flight, but when an unusual condition occurs or a flight plan needs to be altered, the workload may increase dramatically (Ishibashi, 1999). Due in part to a reduced role of the pilot in the aircraft control loops, during the times of high workload the pilot's decision making and performance may suffer from inadequate situation awareness, or comprehension of the factors involved in the current situation.

Although larger air carrier and corporate jet manufacturers' aircraft have incorporated EFIS into their flight decks, little has been done in the General Aviation (GA) market until recently (e.g., Williams, Yost, Holland, & Tyler, 2002). Previous GA aircraft did not employ glass cockpits due to expense, immature miniaturization technology, and a lack of available space in the cockpit. However, a transition to glass cockpit technology in GA is beginning to occur due to the need to present more and more information in formats that a pilot can effectively utilize. To make small aircraft more accessible for greater numbers of pilots and to ease the impact of small privately owned aircraft on the air traffic system, the FAA and NASA have initiated the Small Aircraft Transportation System (SATS) program for the development of highly integrated and advanced technologies for GA.

Given the human factors problems associated with the switch to the glass cockpit in commercial and military aviation, where the pilots are professionals with extensive experience and training, it should be apparent that the potential threat to safety with introduction of the glass cockpit in GA is great. Reduction of this threat requires systematic human factors analyses to guide the design and development of the interfaces. Although glass cockpits are currently being introduced by GA aircraft companies, little thought seems to have been given to human factors concerns. Features of commercial glass cockpits are being incorporated directly without consideration of their suitability for relatively inexperienced GA pilots; little standardization is evident across different company's displays; and training in use of glass cockpits is minimal and unsystematic. These are a few among several human-factors issues that must be addressed for increasingly advanced EFIS technology to be implemented successfully in smaller GA aircraft (Feyereisen & Cundiff, 2001).

Of immediate concern is the need to identify and explore problems associated with the transition of general aviation pilots from “gauge” (analog) style flight information display technology (on which they were initially trained) to highly integrated glass cockpit formats. For example, Jones (2004), in describing his first look at the Garmin 1000 equipped Cessna 172, states, “I have to admit, it is an impressive panel. Usually reserved for the high-end airplanes and airliners, this panel is a video game junkies dream come true. Although it made me a little uncomfortable not having the old steam gauge instruments sitting front and center” (p. 2). In the future, when pilots have been trained from the beginning with glass cockpit displays that have been designed to thoroughly address human factors concerns, there should be a major improvement to aviation safety. However, in the near term, problems associated with transitioning pilots who were initially trained using gauge displays could easily override these benefits if not dealt with satisfactorily.

Because of the need for systematic investigation of human factors issues associated with the adoption of glass cockpit technology in GA, we have begun to conduct an interdisciplinary research program to examine these issues. As part of this process, we developed a research flight simulator that replicates the basic functions of a light, general aviation aircraft, and allows us to control many aspects of the cockpit displays while measuring several aspects of pilot performance. In this paper, we describe the hardware and software used in this research simulator, issues and problems encountered in simulator development, and the decisions made at each point. We also outline the capabilities and limitations of the simulator, and discuss plans for future research using this device.

Simulator Development

Our goal was to construct a research platform that would provide maximum realism, or ecological validity, within a budget of approximately $6,000 (see Table 1). An optimal system would allow us to vary and control design and flight parameters, and to record various the measurements of pilot performance.

To start with, we salvaged a KingAir cockpit shell for use with the simulator equipment (see Figure 1). The front 15 feet of the fuselage had been previously separated from the rest of the aircraft; we cleaned and stripped out this section. We then added new flooring and wall paneling, and supports for the simulator equipment. The nose compartment was converted into the housing for the simulation computers and other related equipment. The equipment and costs are summarized in Table 1. We selected Dell Model GX270 Pentium 4 computers operating at 3.0 GHz, with 1 GB RAM and a 128 MB

Table 1. *Equipment List and Costs for Simulator*

Equipment Item	Vendor	Quantity	Cost
OptiPlex GX270 Small MiniTower—Intel Pentium 4 Processor 3.00GHz, 1GB RAM	Dell	2	$2,310
128MB nVidia GeForce FX 5200 Graphics Card	Dell	2	$206
1224L 12-inch LCD Desktop Touch Monitor	Dell	1	$540
MicroTouch 17-inch CRT Touch Monitor	Dell	2	$869
G90fB 19-inch PerfectFlat Black CRT Monitor	Dell	2	$416
X-Plane	GraphicSim	1	$50
Throttle Panel, Push-button/Toggle switch module, Landing gear module, Autopilot module, etc.	Goflightinc.com	1 each	$1080
Yoke, Flight Controls, Pedals, Sidesticks, etc.	CH Products	1 each	$390
*GL Studio	Distributed Simulation Technology	1	$4,500

* GL Studio was not included in the original price estimate listed in the body of the paper

nVidia GeForce graphics card, to accommodate the large amount of memory needed to display the graphics. As currently set up, one computer handles the external view and the other computer handles the in-cockpit view, and each computer is connected to a pair of monitors via a split VGA adapter cable.

Figure 1. *General aviation flight simulator.*

For the external view, two 19-inch flat CRT monitors are mounted outside the shell just outside the forward windows. The external image is spread across the two monitors to present the simulated outside world visible from the cockpit (see Figure 2). We investigated the use of a projection system to provide a more realistic panoramic view, but the cost required to overcome hurdles in the projection screen resolution and brightness was too high. Initial reports by users have been favorable, indicating that despite some initial "tunnel vision" (due to the lack of view through the side windows) and the small field of view, the CRT displays are sufficiently realistic for the users to report that, after several minutes, they "forget" they are looking at computer monitors and instead treat them as the "real world" view out of the **front windows.**

Figure 2. *Displays of simulated external view and instrument panel.*

For the in-cockpit view, two 17-inch "touchscreen" monitors were fitted into the instrument panel, one on each side of the cockpit, to present the displays seen by the pilot (see Figure 2). The right display is included for use by either a co-pilot or by an experimenter. We selected touch screens to allow us the option of exploring touch-based manipulation of the displays and controls in the general aviation setting. A third 12-inch touchscreen monitor (not shown) was also purchased to explore alternate methods of displaying and entering flight management data.

We opted to go with commercially available flight control software rather than develop our own software. After evaluating two mainstream flight simulator software packages used in the gaming community (Microsoft Flight Simulator and X-plane), we decided on X-plane because of its superior graphics quality and data collection capability. One significant advantage of X-plane is a feature called PlaneMaker, which allows the user to design custom cockpits and instrument layouts. The instruments for the panel can be selected from a database available in PlaneMaker and placed in the locations of the users' choosing. Virtually every flight parameter in X-plane can be recorded, which is a very useful feature for research. X-plane provides a comprehensive list of flight parameters, any of which are selectable by the user. Although X-plane's data recording capabilities appear sufficient for the time being, we also have installed LabView data acquisition software to support more advanced data collection and analysis.

We chose flight controls by CH Products primarily on the recommendations of the manufacturer of the X-plane software. Installation was simplified by their plug and play capability with X-plane. We planned originally to implement controls on both sides of the cockpit, as in an actual aircraft. However, X-plane does not allow two controls to operate simultaneously, which restricts control to one pilot. Thus, we decided to purchase two sidesticks and one yoke so that we could simulate as many aircraft types as possible. Although the realism of the sidesticks is enhanced if they provide force feedback capability, we did not choose to include this capability due to our current budget limitations.

Another major limitation of the X-plane software is that two different cockpit displays cannot be displayed on the two different monitors. For example, it is not possible to run the primary flight display on one monitor and a multi-function display on the other. This is because X-plane does not allow the cockpit to be stretched across both screens so that, instead, both screens show the same image. We hope to overcome this hurdle with GL Studio, the software that we purchased to design custom instrumentation. GL Studio is a reasonably priced software tool that can be used to design glass cockpit instrumentation that can then be linked to the flight simulation software. Given our interest in exploring alternative instrumentation designs, the capability to design our own instrumentation and layouts was a crucial addition to our simulator platform.

Research Agenda

The advanced flight display platform described in the preceding section was developed to address a wide variety of flight instrumentation and training issues. Many of these issues have been identified in the body of literature that has evolved in response to nearly two decades of glass cockpit operations in commercial service. These issues have attracted new interest with the recent development and implementation of glass cockpit instrumentation in general aviation aircraft. The focus of our research effort is to identify relationships between mental models of pilots and advanced instrumentation designs. A primary objective is to identify displays that effectively support pilots' mental models and permit intuitive responses to environmental inputs.

The first stage of this study will be a two-pronged effort to map mental models used by pilots of varying experience levels and to identify differences between current glass cockpit designs used in general aviation aircraft. These steps will be followed by an investigation of cognitive "disconnects" that occur during glass cockpit flight operations. Finally, investigators will attempt to modify display aspects and training curricula to foster improvements to pilot performance in a glass cockpit environment.

The research platform we have detailed provides an inexpensive, yet robust resource to identify key aspects of pilot mental models and flight display efficiencies. It is not, however, a high-fidelity flight simulator that approaches FAA certification standards. Data collected with the platform will more accurately reflect discrete display and performance aspects, and should not be generalized to a complete and accurate flight environment without additional study. Initial subjects will constitute samples of convenience from a general university flight student population, but follow on efforts may address a wider, general aviation pilot population.

We are currently conducting a preliminary experiment that will allow us to more completely define the simulator's capabilities and limitations. This experiment basically explores the difference in recovery times of pilots when they are flying an analog cockpit display versus a glass cockpit display. We are examining the effects of changing instrument design on performance, for example, changing a dial indicator to a vertical tape indicator. Students who recently completed general aviation pilot training will fly a scenario that requires recovery from an unusual attitude, that is, from a situation in which the aircraft is in an abnormal position with relation to the horizon (e.g., being very high nose up). Recovery time will be measured from the instant that the pilot first receives indication of the unusual attitude to when s/he returns the aircraft back to wings level flight and cruise airspeed configuration. The results of this experiment will allow us to become familiar with all details of the simulator and provide an initial step toward accomplishing our longer-range research objectives.

References

Billings, C. E. (1997). *Aviation automation: The search for a human-centered* approach. Mahwah, NJ: Erlbaum.

Feyereisen, T. & Cundiff, C. (2001). Visual cueing and control for general aviation application. *AIAA/IEEE Digital Avionics Systems Conference - Proceedings*, v 1, pp. 5B11-5B15.

Ishibashi, A. (1999). Situation awareness in the automated glass-cockpit. *Proceedings of the IEEE International Conference on Systems, Man and Cybernetics, 3*, p. III-710 - III-714.

Jones, N. (2004). Chesapeake airport open house. *The Flying Wire* (Monthly publication of EEA Chapter 339), July, 04, p. 2. (Downloaded January 31, 2005, from http://homepage.mac.com/chapter339/.cv/chapter339/Public/2004-07.pdf-link.pdf)

Kaber, D. B., Riley, J. M., & Tan, K.-W. (2002). Improved usability of aviation automation through direct manipulation and graphical user interface design. *International Journal of Aviation Psychology, 12*, 153-178.

Williams, K. W., Yost, A., Holland, J., & Tyler, R. R. (2002). Assessment of advanced cockpit displays for general aviation aircraft: The Capstone Program. *FAA Office of Aviation Medicine Reports. DOT/FAA/AM-02/21, Dec 2002, 1-35. US: Aviation Medicine.*