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Communications and Decision Making In The Glass Cockpit

It could be a flight safety hazard to have a pilot in the glass cockpit unless the system is structured to take the best advantage of the human's special capabilities.

by

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The term "glass cockpit" has come to be used in aviation to describe the flight deck of an aircraft equipped primarily with cathode ray tube (CRT) displays instead of traditional electromechanical instruments, although the latter may be installed as standby instruments. Newer civil aircraft currently in airline service — Boeing 757, 767, 737-300, and the Airbus A300-600 and A310 — utilize glass cockpit type instrumentation; the F/A-18 in service with the Royal Australian Air Force is an example of a military aircraft with its CRTs complemented by a headsup display (HUD).

Second generation civil aircraft, including the Airbus A320, Boeing 747-400 and Beech Starship will take the glass cockpit concept even further. The "big picture" cockpit display being researched and developed by McDonnell Douglas explores new CRT applications in military aircraft. In the big picture cockpit there is only one very large CRT which displays information to the pilot.

The computer-driven CRT has given designers great flexibility in display format and in the amount of information that can be displayed. At present, most glass cockpit CRTs mimic electromechanical displays, at least for primary flight instruments, related to the transfer of pilot training from the old- to the new-generation aircraft. However, there is no technical reason why this is necessary, and special-purpose human factors research simulators, such as at U.S. National Aeronautics and Space Administration (NASA) Ames are being used to explore the effectiveness of multicolored CRT display formats unrestricted by constraints of previous training or instrument hardware.

Introduction of Digital Computer Technology

CRTs, however, are only the most obvious and visible manifestation of the revolution that is occurring in aircraft technology. The application of new digital computing technologies based on the microprocessor not only drives the new CRT displays, but also underlies virtually all other aspects of the operation of the aircraft. For example, the A320 will be the first commercial airliner to employ full fly-by-wire (FBW) flight control systems.

As well as changing the appearance of the cockpit, with its array of CRTs and their interchangeable and often time-shared displays, the new technologies are rendering obsolete many long-established patterns of crew communication and decision making.

Cockpit resource management (CRM), which is applicable to all multicrew aircraft, will not be discussed here. This article addresses some of the challenging human factors issues concerning crew communication and decision making which will be further exacerbated with the introduction of second generation glass cockpit aircraft, such as the A320 and the two-pilot crew Boeing 747-400.

Automation: Effect on Communication and Decision Making

Communication and decision making interact, and both are affected by the increased levels of automation associated with the glass cockpit; the greater the extent of this automation, the greater will be that effect. Traditionally, the concept of communication which implies a dialogue that evokes greater understanding between the participants, has been applied primarily to the crew and not the aircraft, or machine. Human factors specialists refer to the man-machine interface and the optimization of information transfer across it. In the glass cockpit, the choice of CRT display format, symbology and color coding, for example, falls into this category, which remains critically important in its design. These considerations, while essential, do not really go beyond the basic level of information transfer, and information can, of course, be readily transferred without understanding.

In the glass cockpits of the near future, the extremely high levels of automation and the increasing prevalence of "expert" system -utilizing artificial intelligence software — for example, in new generation single-seat advanced technology fighters foreshadowed by aircraft such as the Dassault Rafale and the Grumman X-29 — mean that the concept of communication or dialogue between man and machine becomes important as that between humans. Man and machine will have to work together to make decisions, and the crew's contribution will be only one of many inputs to the aircraft's computerized control systems.

Cognitive Ergonomics

The continued development of voice input control (as being pursued in the U.S. Army's LHX advanced singleseat attack helicopter program) and, in the future, thought control, of aircraft systems, together with more advanced synthesized speech technology, will tend to make the man-machine communication more human in character, at least on the surface.

Consequently, the optimal matching of the software, i.e. the "thought processes" of the aircraft systems, to the thought processes of the man, has become perhaps the major human factors challenge in the design of civil and military glass cockpits. If the pilot does not understand the conceptual frame of reference and the basic logical processes underlying an aircraft's automated systems, catastrophic communication breakdown between pilot and aircraft may be the result. Consequently, the decision-making capability of the pilot or crew will be severely degraded.

The aircraft computers not only have to be user friendly, but they must also allow a meaningful dialogue with the pilot to facilitate decision making. At a very basic level, fourth generation computer programming languages, which are close to natural spoken language, are examples of this kind of cognitive matching - a new and alien way of thinking does not have to be learned by the human to communicate with the computer. New terms have been coined to cover this rapidly expanding field, such as "cognitive ergonomics", or "behavioral engineering"; it is now a recognized area of substantial research activity.

Automation: Effects on Crew Performance

The automated systems of the glass cockpit have continued a process of change which began with the first reliable autopilot -that is the change in the role of the pilot from an aircraft controller to that of a systems manager whose primary task is to monitor the aircraft displays and detect any deviations from the desired parameters. With the extremely high reliability of present multiple-redundant computer systems, such deviations are of very low probability. This is a classic vigilance task.

There are numerous instances where the inherent limitations of humans in monitoring automated systems have led to accidents or near accidents, particularly when combined with the effects of fatigue or circadian disrhythmia.

Because aircraft accident and incident investigations, as well as laboratory and simulator research, have shown that existing aircraft automated systems can adversely affect crew communication and decision making, the effects of even greater automation on crew behavior are disquieting. The main reason for the retention of the pilot in the glass cockpit in these days of multiple redundant, fully-automated navigational and flight management systems (as in the cruise missile), is because of the pilot's "remarkable capacity to analyze, seek novel solutions, and extrapolate beyond his ‘program’.” (Wiener, 1986). The serious problem confronting designers is that the extreme nature of the new glass cockpit automated systems may further degrade the capability of a pilot or crew to exercise these uniquely human capabilities. The recent case of the China Airlines Boeing 747 which rolled inverted and dove 31,000 feet during a flight to the United States, is an excellent example of this kind of problem. The U.S. National Transportation Safety Board (NTSB) accident investigation concluded that the captain of the aircraft was not significantly affected by boredom, monotony, or circadian disrythmia, but over-reliance on the automated systems of the aircraft did affect his performance.

Over-Reliance on Automated Systems

There is already some evidence from accident data that the new, very highly automated systems can lead an over-reliance on them by the pilot, resulting in loss of situational awareness. The total automation of the pilot’s former active control functions, and now the increasing automation of the remaining monitoring functions as well, may induce a mesmerized, trance-like state of lowered arousal in the cockpit, even in the absence of any fatigue factors. The consequences for the immediate detection of a problem and the subsequent rapid response of a two-man crew of an ultra -long-range, fully-automated glass cockpit Boeing 747-400 at about 4 a.m. on the last stage of a trip are not promising. Even with present technology, a recent case occurred in which a Boeing 747 gradually lost cabin pressurization over a 40-minute period without any member of the crew noticing the problem, which was being accurately displayed to them on their instruments throughout the incident.

The point is that, in the light of the vast amount of research and accident and incident data available on human performance in these situations, it is unrealistic to expect, let alone to count on, optimal communications and decision making by pilots operating under such conditions in the glass cockpit, unless some fundamental changes are made to the philosophy and practice of aircraft systems design, crew operational practices and procedures.

Glass Cockpit Human Factors: A Possible Solution

The human factors problems described in this presentation are formidable and their implications for flight safety are enormous. However, solutions to these challenges are being researched. Fortunately, the flexibility of present digital computing systems enables many solutions to be explored — particularly in the areas of man-machine communication and decision making.

A leading researcher in this area is Professor Earl Wiener of the University of Miami and NASA Ames. He has proposed the concept of the “electronic cocoon.”

Wiener, an experienced pilot, contends that the one reason all the automated equipment is on board is to help the pilot do his job. Given this basic premise, he argues that “within the bounds of safety and regulatory conformity, the pilot should fly in a manner he sees fit, using cockpit resources as he deems necessary.” This pilot autonomy requires that the crew should be backed up by an enhanced warning and alerting system, a multivariate electronic cocoon around the plane. As long as the plane stays within the cocoon, let the pilot select his equipment and style of flight as he sees fit. If he punctures the cocoon, the system will warn him (possibly gently at first, with increasing stridency if he fails to respond).

This concept has many benefits in terms of the points discussed earlier. For example, the pilot has far more input to the operation of the aircraft — he does not merely sit back and monitor the aircraft systems, just watching what the aircraft is doing. This provision would maintain the arousal level of the crew by means of their increased active rather than passive communication with the aircraft systems. Under certain conditions, the aircraft computers might present a range of options upon which the crew’s decision is required; the crew may interrogate the computer to assist them in understanding why it has arrived at various options.

The crew may suggest or explore with the computer additional solutions to a given problem and may input new information for the computer to evaluate.

Dialogue with the aircraft computers would become an integral part of cockpit resource management practices. The crew under Wiener’s concept are no longer passive monitors, a role that humans perform far less well than machines. Because of their active interaction with the aircraft computers, the pilots will have a far greater understanding of the frame of reference of these systems.

Once outside the prescribed limits of the electronic cocoon, however, the automatic systems would warn the pilot and, if ultimately necessary (for example, if the crew did not respond sufficiently rapidly), take control to remove the aircraft from the crisis situation. Much of the technology required to achieve this already exists. An increasing number of airlines now monitor crew performance on every flight by means of quick-access flight data recorders. If an aircraft is found to have deviated from specified limits, (e.g. an unstabilized approach), this is flagged and the incident is discussed with the crew in a debriefing session.

The U.S. Air Force recently let a contract to develop a system that will allow aircraft computers to take over and fly an aircraft out of trouble in the event of G-induced loss of consciousness of the pilot. Wiener uses the example of collision avoidance systems currently under development in which the aircraft computers take the decision for evasive action away from the crew, if necessary.

Maintaining a Balance

This article has discussed some of the most important and challenging human factors problems affecting decision making and communication in the glass cockpits of today and tomorrow; there are, of course, many others, including problems of software design and integrity for the computerized systems.

However, as long as the pilot is considered necessary in the cockpit, then the system with which he interacts must be structured to take the best advantage of the human's special capabilities. If this is not done, then, as some aircraft accidents in which automatic systems have been catastrophically overridden by the pilot have already shown, it may be a serious flight safety hazard to have a pilot in the glass cockpit at all. ♦

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