The Future Flight Deck: A discussion paper by the flight operations group of the royal aeronautical society and the guild of air pilots and air navigators of London

Authors: Russell, M. C. & Everett, C. G. C.

SUMMARY

This paper is not a research or academic paper but one that sounds the voices of pilots about the way the flightdeck should be laid out. Pilots are the end users of flightdeck technologies and their voices are often not heard by designers, manufacturers or certification agencies. If safety has been the driving force behind the recent changes of the flightdeck, safety means very little if pilots cannot find equipment to be “user friendly.” EFIS (electronic flight instrument system) displays, in particular, can cause pilot confusion and often require substantial training.

[Outline of paper and why sections are important]

This paper is divided into the following eight sections: 1) The role of the pilot and the development of automation in future aircraft, 2) The flightdeck layout and working environment, 3) Instrumentation, 4) Flight management systems, 5) Autopilot and autothrust, 6) New technology, 7) Concorde’s successor, and 8) Conclusions. A proper discussion of the evolution of the flightdeck requires a discussion of the roles of the pilot. While technological advances are important, designers must keep in mind that many aircraft, for many years to come, will still be landing at unsophisticated airports and, therefore, must still be able to operate aircraft using basic equipment. Pilots must continually modify every aspect of the aircraft (including passenger comfort) and update the course of action in response to instrumentation challenges, weather conditions and minor problems. Because the flightdeck must provide the pilot with information about the aircraft for informed decision making, the flightdeck needs to be designed in such a way that pilot interactions are not challenging. The pilot’s role with the flightdeck should be the central theme of flightdeck design.

[Need for intuitive automation and feedback to support pilot SA and reduce workload]

A desirable level of workload and situation awareness is seldom achieved through flightdeck design. The flightdeck should not automate every aspect of the flight such that the pilot is understimulated and it should not allow the pilot to be overloaded and overstimulated. Some straightforward tasks and routine operations should not be automated in order to optimize the pilot’s level of arousal and to maintain SA. Innovative technology should not cognitively tax a pilot nor force the pilot to undergo specialized training to operate it or interpret its feedback, but rather it should be natural and instinctive to use. Automation does not necessarily reduce human error and so innovated technology should present information in a clear and unambiguous way. Instrumentation also should not distract crews, present information that preoccupies crewmembers, or provide information inappropriately.
Automation design needs to consider training implications and human capacity

Currently, higher levels of training are required with new technology implementation because aircraft systems are not providing sufficient intuitive feedback that allows crews to understand what the systems are doing and how they are all interacting onboard the aircraft. It is questionable whether new cockpit technology is really aiding the pilot or if it is aiding ATC. Improvements in automation technology can help humans accomplish new and more difficult tasks but they should not increase system output beyond human capacity limitations to operate manually in the event of instrumentation failure. “Many pilots see much of this new [cockpit] technology as superfluous, particularly where it impinges on airmanship and decision-making (p. 8).”

Types of cockpit automation and pilot perception

There is a widespread misunderstanding of the meaning of automation and how it is applied to the flightdeck. The first type of automation that comes to mind is the kind that’s been available for a long time, like autopilots and autothrust (that do not make decisions for the pilots but rather help them). Then there is automation that operates and controls the systems, requiring little pilot input. Lastly, there is the type of automation that makes decisions for the pilots. Some pilots are opposed to using automation because it means less hand flying. Others think it means better systems control and they are in favor of its utility. Still, others are apprehensive about letting the aircraft make decisions that affect passengers safety and for which they can be legally and morally held accountable in the event of automation error.

Concerns with instruments, displays and controls

With respect to flightdeck displays and instrument lighting, designs should conform to a few basic principles: 1) Pilots should be able to adjust lighting in the instruments and around his/her seat. Chart lights should shine on the paper and not on the back of the writing hand. Many of the older aircraft had better lighting conditions than the newer “glass cockpits”. Glass cockpits sometimes suffer from inadequate dimming capabilities. External cameras should continue to be developed in order to allow the pilots to see the wing tips and other aircraft parts; however, such displays can be troublesome at night and in adverse weather conditions. Cameras can be particularly useful in identifying engine fires.

Controls and switches should be harmonized. The operation of all controls and switches should conform to conventional thinking in terms of the indications of direction and movement. Roof panel mounted switches are often struck by crewmember heads when entering or leaving their seat. There must be some consideration of the necessary size, shape and position of each control or switch. For example, in turbulence, there is a risk of selecting the wrong switch for the flap lever. This can be avoided by using a larger, more centrally located button. Manufacturers should be aware that many airlines expect crewmembers to be both a handling and non-handling pilot; therefore, the controls should
be equally accessible from either seat. Therefore, it might be more advantageous to operate some control functions from a control column or side stick (accessible by pilot and co-pilot), as is done in some military aircraft. In some instances, one or two hands are needed to operate instrumentation (e.g., the FMS) and this may not be practical in certain flight situations so alternative instrumentation access methods need to be developed.

Roof panel controls and indicators often cause performance problems because the panels are difficult to see (particularly if they are too close to one’s face) and they are laid out in a uniform style making it easy to select the wrong control. In addition, the switches and knobs are of the same design adding to the confusion involved in incorrect selection. The authors recommended using larger switch labels or touchscreen substitutes for system indicators and switches. Instrumentation switches and displays are not standard across aircraft and perhaps they should be.

Autopilot is well used in modern aircraft and yet it is unsatisfactory. Airspeed, altitude and heading selectors are often the same size and similar shape and usually set in a line with uniform spacing. Some selectors are difficult to use and set. Communication controls are more frequently used than autopilot and yet they are also arranged in uniform rows of similar buttons whose position is often difficult to observe. “Some boxes make all the button level whether “on” or “off”, but illuminate the ones that are “on”, depriving the pilot of the ability to feel the position of the button, and relying on a level of illumination that may be inadequate (p. 13).”

[Perceptions on “glass cockpit” displays and recommendations]

Instrument flying was developed after the First World War, followed by mechanical and electromechanical instruments that evolved into the 1970’s. Complex instruments like flight directors, ILS presentations, fast-slow indicators and high speed limit indicators all were implemented without the pilot needing to learn new instrument flying methods. However, the glass cockpit displays made alternative presentations possible over a short time and required the pilots to adapt their instrument flying technique to cope with new instruments. These new instruments have enhanced safety; however, some pilots feel that the incorporation of the glass displays was a regression because it introduced new instruments that are difficult to interpret. Flight instruments paint a picture of the outside aircraft field of view. They must be simple, easy to use, and capable of interpretation with minimum thought processes; especially in rapidly changing situations. In high stress situations, they should be natural and intuitive and should not tax the mental capacity of the pilot. They should be the same style and presentation as the main instruments because in emergency situations, an unfamiliar design could increase pilot workload. The problems with modern instrumentation fall into two general categories: 1) Clutter has increased within the PFD and ND, and 2) Special pilot training is needed because modern screen presentations can be associated with automation and other systems that make the pilot remote from the information he/she is trying to use.
[Comments on specific instrumentation and advantages of historical design]

The altitude indicator (AIs) is the only instrument that shows non-ambiguous orientations in clouds, at night or in severe weather because it helps the pilot to fly within the structural limits of the airframe and forms the basic reference for flight in emergency situations. AIs are easy to read and have appropriate color patterns for sky and the ground and should be used as an example for future instrumentation design.

The ASI (airspeed indicator), altimeter and VSI (vertical speed indicator) have suffered from having to be adapted to a strip display. The introduction of the servo-altimeter was a great advance above a confusing three-pointer presentation because it was easy to read, easy to interpret the rate of change of altitude and easy to acquire height information. The VSI tends to become lost in the clutter of the PFD so it has been given a reduced role in recent years.

The ND is usually positioned beside the PFD. The position, shape and selections of the controls should be standardized across aircraft to eliminate the need for pilots to re-learn new controls each time they are in a different aircraft. A common standard set of symbology would also help to reduce training time. There is a tendency for the NDs to be cluttered with unnecessary data. The presentations of the data should be adjustable and tailored to the pilot’s preferences where it can be.

[Information volume and types in glass cockpit displays]

The introduction of glass cockpits have allowed an enormous amount of information to be displayed in modern flightdecks. The information displayed on screens may be somewhat variable depending on the amount of space available. Some may have screens dedicated to secondary information such as engine and systems readings, systems schematic diagrams and normal and abnormal checklists. Checklists on screens can generate more problems than they solve; particularly in emergency situations where the pilot has difficulty dealing with the emergency and the checklist at the same time.

[Summary of high-level recommendations]

The following summary points should be considered when designing flight instrumentation:

1. The primary flying instruments should be a dial presentation.
2. Basic aircraft operations should not fall in the pilot’s peripheral attention but, rather, they should be an integrated part of the pilot’s activities.
3. Systems should be simple, easy to read, instinctive to interpret and operate.
4. Pilots can only absorb a certain amount of information at once.
5. All formats, color coding, control positions and operations should be standardized.
6. Line pilot viewpoints need to be communicated to the designers and manufactures.
[FMS criticisms and design recommendations]

The flight management system (FMS) allows the pilot to interface (through a keyboard and screen) with the aircraft navigation and performance computers so that the system can effectively control the autopilot and autothrust along a pre-set flightpath. The FMS was designed to reduce pilot workload but this is questionable because when workload is high, it tends to amplify the load to the point where operation without the FMS might be safer and simpler. The key to a better FMS is the implementation of a higher quality interface. The design parameters in an FMS should be dominated by one requirement - making the interface with the pilot as simple and logical as possible, from the pilot’s point of view. The CDU (control and display unit) is the medium with which the pilot communicates with the FMS and it usually consists of the small screen and an alphanumeric keyboard. The CDU has some deficiencies and a different keyboard with a roller ball or “mouse” control might prove more helpful. Whatever changes occur, the CDU design should aim to keep typing volume down to a minimum since it is time consuming and can be prone to inaccuracies. Also, an ‘execute key’ can be included. Font size (instead of font color) can be used for visual enhancement.

This paper recommends the inclusion of five features in the FMS to enhance usefulness: 1) temperature deviation indicators, 2) a “fix” page inclusion to allow radials and “abeam” positions from selected waypoints to be given, 3) position and distance from a waypoint on current track, 4) cruise information should include the track and distance between every waypoint and fuel remaining at every waypoint and, 5) “delete” or “return to previous condition” buttons need to be included.

[Autopilot control modes and pilot confusion]

The autopilot was first introduced as a simple device to control aircraft attitude while allowing the pilot to attend to another task. By the 1950s, it was possible to use the autopilot to fly approaches coupled with the ILS. The autopilot previously had only a few modes but currently, there are too many modes that end-up confusing the pilot more than they help them. In fact, some modes change without pilot input. Instrumentation should provide enough feedback information about the aircraft in order to cross-check or confirm the proper functionality of the autopilot. The autopilot should be a tool used to reduce workload and should be kept as simple as possible. Interaction with other systems like the autothrusts and FMS should be logical and intuitive. “Full flight authority autothrust systems seem generally to work well without generating too many problems of their own, although accuracy of speed holding sometimes leaves much to be desired (pp. 24).” Some are more instinctive to use than others, particularly ones that allow thrust levers to move, providing tactile feedback.

[HUD and SVS design recommendations]

HUD displays and synthetic vision systems are also covered in this paper. To provide safe approaches with respect to terrain, the pilot needs to see the ground. Synthetic vision would aid in ground maneuvering in low visibility conditions. IR (infrared sensors) is
thought to provide more warning of windshear, clear air turbulence and vortex generation in mountain regions, in addition to the use of synthetic vision. The HUD can be used to achieve a lower approach minimum and can be either a primary source of information to monitor the autopilot in poor visibility or it can be a monitor of performance on approaches. The generation of symbology enhances safety when operating at night, especially in airfields with no approach slope guidance. The symbology should be consistent between heads-up and heads-down panels. The flightpath vector symbology needs to be re-evaluated such that it mainly shows pitch information because lateral information can lead to disorientation. (This may be attributable to conformal scaling of lateral position indicators within the FOV of the HUD.) In the future, HUDs are likely to be the primary means of displaying information during the critical stages of flight, integrating several graphical displays to provide precise guidance and high situational awareness. Therefore the HUD is advantageous because all of the vital information can be in one place with a “pathway in the sky” that enhances situational awareness.

Finally, the FMS should be replaced with knowledge-based systems, and the use of HUDs and SVS technology needs to provide approach and landing capability in any weather condition at any runway, regardless of whether the airport has the proper instrumentation needed for each runway. “It is time to look beyond the choice of a landing aid that has to be installed at every runway to provide bad weather approach capability and develop the equipment to allow an aircraft to land at any runway, in any weather, generating a safe approach path with its onboard systems (p. 28).”

COMMENTS

This paper was written in 2005 (2 years from the current review date). Since technology is rapidly changing, an update to the opinions offered in this paper may be critical to future cockpit systems design.