

Information Integration in the Glass Cockpit

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Abstract

This paper focuses upon information presentation in the glass cockpit. In particular we show how information presentation can be redesigned to aid pilots in having a better understanding of the automation state and its future behavior. This is illustrated with an example from the A320.

Introduction

We know, from a series of studies on automation behaviour in glass cockpits (Sarter et al 1997), that a lack of pilot "Situation Awareness" is a (if not *the*) primary concern for those who work in the area of flightdeck safety.

This complex phenomenon has been shown to have a number of potential causes, ranging from surprise at the actions of the increasingly autonomous automation, to confusion over the state of the automation (Sarter et al 1995).

Previous studies have shown that, in this environment, the absence of relevant information, or misunderstanding of available data, can lead to undesirable decisions and actions on the part of the pilot. A poor understanding of both environmental data and automation activity has been a key factor in the build-up to major aviation incidents (ACRC 1996, BEA 1992).

Endsley (Endsley 1999) suggests three steps to achieve situational awareness (SA): (1) perception of the automation state; (2) understanding of the situation; (3) anticipation of the future state of the system. We use this description as our working model, in order to examine the various problems inherent in the scenario described below.

In this paper we review problems of information distribution. Specifically, we refer to the recovery from an erroneous entry of a vertical descent speed (VS) of 3300 feet per minute rather than the flight path angle (FPA) of 3.3 degrees, which is believed to have occurred during the crash of the Air Inter over Strasbourg (BEA 1992). Then we present a suggestion for the redesign of the Primary Flight Display (PFD) to support better SA.

Analysis of the Problem

Given Endsley's view of SA (Endsley 1999), *perception of the automation state* is made more difficult by the fact that

the input device, Flight Control Unit (FCU), used to configure the aircraft for descent, is physically separated from the principal output device, the PFD. The same separation of complementary information (mode 'V/S' and value '-3.3') exists *within* both FCU and PFD.

The understanding of the situation is made equally difficult. There is some inconsistency in the presentation of information on the FCU and PFD. For example, the vertical speed, shown in feet per minute on the FCU, is described in 100's of feet per minute on the PFD.

Moreover, the pilot, expecting to have entered an angle of descent (FPA), has to calculate the corresponding vertical speed (the parameter shown on the PFD), before checking it against the VS shown on the display. The pilot has to do these calculations to *anticipate the future state of the automation*, which increases cognitive load.

In sum, from our description of the A320 FCU and PFD, and the task of checking an erroneous VS entry, we can see that the pilots are faced with a number of barriers to the perception of the automation state, computation of current state and prediction of the future state. The extra time and effort, which is required for these tasks, leads to increased cognitive load for the (already busy) pilot.

Proposed Design Solution

A screenshot from our redesign is reproduced in Figure 1. We believe that this redesign assists the pilot's achievement of SA more effectively in the following ways.

1. Perception of the automation state: The basic information needed by the pilot is collected on a single, coordinated graphical display – i.e. a single source to provide information on both current system state and activity. Information is presented to describe current heading, current altitude, vertical speed and prevailing ground elevation.

2. The understanding of the situation: Information is now presented in a way that causes less computation for the pilot. The computations needed to convert FPA to VS on the original display are avoided – a simple graphic describes the VS in relation to other system parameters,

whether originally entered as a vertical speed or as an FPA.

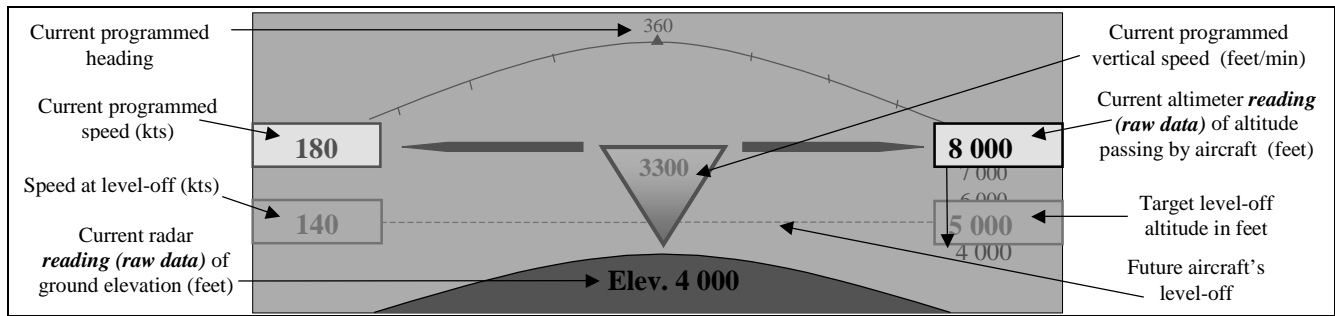


Figure 1. New partial prototype of PFD showing improved integration of information and reflection of automation state.

3. Projection of future states: The biggest advantage of our redesign is the support it gives the pilot in the instantaneous projection of future aircraft states. At the heart of this effort is the new graphic representation explaining the aircraft state in relation to environment through integration of information of the altitude (right hand boxes and dotted line), vertical speed (central triangle) and ground (the shaded arc at the bottom of the screen).

These three elements are used to assist the pilot in “staying ahead of the plane” in the following ways.

Firstly, the target (i.e. anticipated) states for current activity are clearly shown. For example, target altitude is shown as a dashed line on the graphical display allowing the pilot to estimate the short-term future in relation to critical parameters at a glance (also shown as a number in case an accurate reading is needed). Equally, the level-off speed is shown in the lower left hand corner of the screen.

Secondly, the combination of vertical speed indicator (the triangle in the centre of the screen), altitude scale (right hand tape) and the horizon (the arc at the bottom of the screen) are used to show proximity to the ground. At any given time, the height of the triangle corresponds to the vertical descent (ascent) projected in the next minute (taller=faster). The tip of the triangle is now not randomly placed, but is coordinated with the right hand altitude scale. The faster the rate of descent, the longer the triangle becomes. The darker the shade of the tip becomes, the closer it comes to the boundary of the envelope within which it is safe to fly. If the tip of the triangle is below the arc, the aircraft is anticipated to be on the ground in less than a one-minute’s time – fine if the pilot is trying to land, not so in any other case.

Lastly, an ascent is shown by an upward pointing triangle and descent by the reverse. Thus, the rate (and direction) of change of the altitude (i.e. the vertical speed) is presented clearly to the pilot. This display allows a smooth scale of vertical speeds to be displayed in a way that the current PFD does not. When trying to anticipate the future state of the plane, a quick glance at a graphic now suffices, rather than a lengthy process involving understanding of automation state.

In the example shown in Figure 1, the pilot can see straight away that the aircraft is about to overshoot the desired level-off altitude of 5000 feet. Action must be taken in less than a minute to avoid collision.

Conclusions

Since situational awareness has been identified by the industry as a major concern, we have argued for a principled redesign of the PFD, in a manner that removes many of the more obvious flaws described above.

With this in mind, we have suggested a prototype replacement that supports the pilot in integrating the information required to assess the current state of the plane, and also supports anticipations of the plane’s behaviour. In this way, we believe that we have demonstrated that both the integration of information and the decrease in pilot cognitive load are achievable through the redesign of the PFD.

In sum, we have identified a potential solution to overcome factors impeding pilot performance, thus improving flight safety.

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