PILOT PERCEPTIONS ON THE INTEGRATION OF ELECTRONIC FLIGHT BAG INFORMATION IN NEW FLIGHT DECK DESIGNS

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The purpose of this study was to gather usability data on a new flight deck concept in which pilots are shown certified and uncertified information concurrently on installed avionics. Specifically, we wanted to examine perceptions on the concepts of *concurrent use* and *differentiation* for electronic flight bag (EFB) applications that show ownship position. We presented an uncertified electronic chart on either a portable electronic device (PED) alone (off to the pilot's side) or on both a PED and an installed flight deck display. The uncertified electronic chart was always shown concurrently with an approved navigation source. We differentiated the electronic chart from the navigation information via display medium (portable vs. installed) and a header labeled "EFB," drawn at the top of the uncertified electronic chart on the installed display. Thirteen flightcrews flew eight scenarios using the flight deck concept. Pilots liked the concurrent display of the electronic chart, and the repeated display functionality, in particular, because they could *control* the presentation of information on the forward display using the touch screen on the side display. Our method of differentiation—a header—was less successful and suggests a need to consider the potential for stimulus habituation when evaluating these techniques.

INTRODUCTION

Information integration on the flight deck affords system designers the opportunity to display what were traditionally considered "electronic flight bag" applications (e.g., electronic charts, electronic documents, etc.) on installed avionic systems. These information sources all have different levels of accuracy, integrity, and reliability. Electronic flight bag (EFB) software applications are not formally "certified;" the failure of these applications is considered to be minor or to have no effect. On the other hand, software that is approved (or "certified") is reviewed to meet an appropriate design assurance level based on the intended function specified by the manufacturer.

The display of ownship position on EFB applications for use in-flight has been discussed extensively. In 2017, the Federal Aviation Administration (FAA) updated their policy on the use of EFBs to allow the overlay of ownship position on EFB applications "*only when the installed primary flight display, weather display, or map display also depict ownship position*" (Advisory Circular [AC] 120-76D, Section 11.17). Furthermore, AC 120-76D, Section 11.17.1 states that "*Operators must ensure flight deck crewmembers understand the proper use of EFB ownship position, including the need for concurrent use and differentiation. The flightcrew's reference for maneuvering the aircraft in the air is the installed primary flight and navigational displays; therefore, they must be able to resolve conflicts between the EFB information depicted on the 'secondary' display and the installed avionics system identified for each EFB application as its reference for in-flight use.*"

Thus, AC 120-76D introduces the concepts of *concurrent use* and *differentiation*. The concept of differentiation—that is, ensuring that pilots understand there is a difference in the underlying data—is relatively clear when an EFB application is presented on a portable device, but less clear for EFB applications shown on installed displays that are integrated into the flight deck. The concept of concurrent use is also not well-defined in terms of implementation. Therefore, the purpose of this study was to explore these ideas by examining the usability of a new flight deck concept in which flightcrews use EFB information (an electronic chart) that is presented both on an installed display in front of the flightcrew and on a portable device off to the side. We were particularly interested in whether the location of the information and the level of pilot workload (as manipulated by manual flying vs. autopilot) influenced pilot decision making.

Joslin (2013) reported that a portable electronic device (PED) or EFB may distract attention from the primary flight display. It is not clear whether this distraction is because the portable electronic display is peripherally located, or if it is because of the features of the information being shown that may make them compelling such as color, frame of reference, or moving aircraft symbol. Yeh, Jaworski, Thomas, Kendra, and Hiltunen (2018) examined whether the presentation of ownship position on a taxi map used in low visibility conditions would be compelling enough to divert flightcrew attention away from the out-the-window (OTW) view. The results showed that the Captain, whose primary responsibility was taxiing the aircraft, spent more time looking at the taxi map display when ownship was presented than when it was not. The time spent looking at the map was borrowed from the time that would have been spent looking out the window. There was no difference in the time First Officers looked at the map as a function of ownship presentation. The change in the Captains' scanning behaviors was not considered to be a distraction because there was no negative impact to taxi performance, nor was there a difference in the likelihood of detecting a failure in the depiction of ownship position.

Carroll, Wilt, Sanchez, and Carstens (2019) conducted a series of interviews with general aviation and air transport pilots to examine how pilots make decisions when they are presented with information conflicts on an installed display vs. a portable display or on two installed displays. The results indicate that pilots are generally used to seeing conflicting information and continuously evaluate information with varying levels of integrity to determine what is "truth." Pilots decided to use an information source based on several factors: (1) if that source indicated that situation was more hazardous, (2) if pilots trusted the information, (3) if they were trained to use that information, (4) if pilots knew that information was "certified," or (5) if the immediate action was required.

We wanted to examine how pilots integrate EFB information when that information is presented on an installed flight deck display concurrently with a certified navigation source, and how they resolve conflicts if the information differs. Additionally, we were interested in understanding how to differentiate the sources of information. The focus of this paper is on pilot perceptions of a new flight deck concept, in which an uncertified electronic chart is integrated into the forward display panel. The pilot perception data described here are the first half of a larger study to understand pilot behavior when integrating EFB information on certified avionics.

METHOD

Participants

Twenty-six Airline Transport Pilots participated in the study. The age range for the participants was 41–50 years old. The median flight hours for the participants was 3,700 hours; with a range between 50 and 25,000 hours. Pilots were paired to form 13 two-person flightcrews. Flightcrews were comprised of pilots from the same company to minimize differences in standard operating procedures. Each participant flew the same position in the study as in flight operations.

Simulators

Figure 1 shows the simulator, which was designed to behave like a Boeing 737. There were four large displays on the forward panel, two in front of each flightcrew member. Two PEDs with 10" screens were fixed in place on the left- and right-side flight deck windows (labeled A in Figure 1). All displays were controlled by touch.

The primary flight display was always shown on the outermost displays (labeled B in Figure 1). The two inner displays were divided into two areas (C and D in Figure 1), which each measured 10.9" diagonally. In the "traditional" configuration, i.e., when we presented the electronic chart on the side display only, we showed the navigation display in area C. In the new flight deck concept in which EFB information is shown on the forward panel, we presented the electronic chart application in area C and moved the navigation display to area B so that it shared space with the primary flight display. Engine information was always shown on the innermost displays (labeled D). This layout is a flight deck concept only and has not been approved by the FAA.

The electronic chart information on the PED and the front panel was repeated and mirrored such that pilots could interact with one display (e.g., dragging a finger to pan or pinch to zoom in or out), and the changes would be reflected on both displays. The electronic chart shown on the front installed display (C) was almost identical to the information

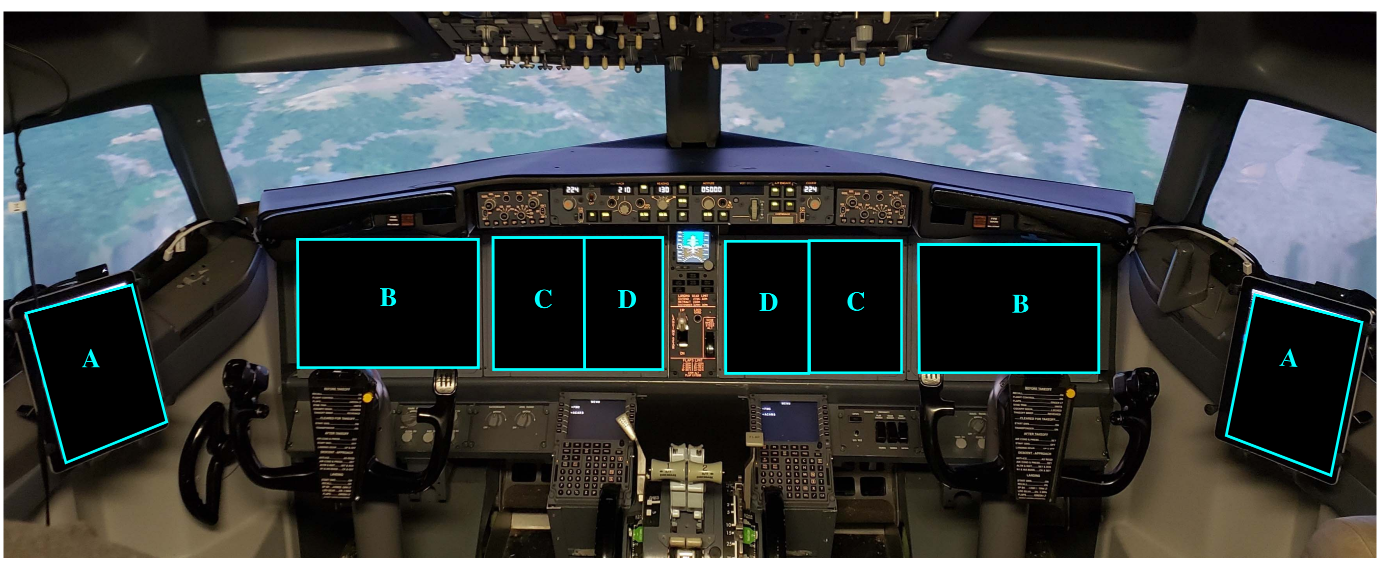

Figure 1. Flight deck layout (concept only). There are four display areas. Area A is the PED. When the electronic chart was shown only on the PED, Area B contained the primary flight display, and Area C contained the navigation display in Area C. When the electronic chart was shown on both the PED and front displays, Area B showed the primary flight display and navigation information, and Area C contained the electronic chart. Engine information was shown in Area D.

shown on the PED (A). There were two differences. First, the electronic chart was slightly smaller when it was presented on the installed display than on the portable device due to the difference in the screen sizes of the PED and front panel. Second, when the electronic chart was shown on the installed avionics, we drew a 1/4" blue header on the chart that extended the width of the display with the label "EFB" to differentiate that information from the approved navigation information shown concurrently on display B. Differentiation of the electronic chart information on the side display was achieved simply by the different display mediums.

Experiment Design

The study was a 2 (display location: side [PED]) vs. center+side [installed display + PED]) x 2 (workload: manual flying vs. autopilot) within-subject design, as shown in Table 1.

Table 1. Experimental design.

		Workload	
		Manual Flying	Autopilot
Location	Side	2 Scenarios	2 Scenarios
	Center + Side	2 Scenarios	2 Scenarios

Flightcrews flew scenarios using an electronic charting application showing ownship position. In the side condition, the electronic chart application was shown on a PED, located to the left or right side of the flight deck. As noted previously, differentiation in the side condition was accomplished via the display medium. In the center + side condition, the electronic chart application was shown on the forward panel, next to an approved navigation source, as well as on the PED. Differentiation was accomplished via display medium (for the PED presentation) and via a blue header with a label "EFB" (for the front panel presentation).

Scenarios

Each flightcrew completed three practice scenarios to familiarize themselves with the simulator. They then flew eight scenarios—four departures and four approaches. All scenarios were conducted in a simulated daytime environment. No traffic aircraft were presented in the scenarios.

All departure scenarios began with the aircraft lined up on the runway for departure. The flightcrew loaded the Standard Instrument Departure (SID) chart and briefed it before the scenario began. A pseudo air traffic controller then cleared the aircraft for take-off. The departure scenarios were constructed such that the scenarios concluded just before the aircraft position would no longer be shown on the map so the flightcrew did not need to change to another chart. Departure scenarios lasted between 8–10 minutes.

Approach scenarios began at a pre-determined point on a Instrument Approach Procedure (IAP) chart. As with the departure scenarios, the flightcrew loaded the IAP chart and briefed it before the scenario began. Once the scenario started, air traffic control provided instructions for the approach and then cleared the aircraft for landing. As part of the scenario, flightcrews conducted the pre-landing checklists and configured the aircraft for landing. Approach scenarios lasted between 8–10 minutes.

The simulator cab was video-linked to a control room, where an air traffic controller provided communications. Half the scenarios were conducted with the autopilot turned on; the other half were flown manually, i.e., without autopilot or autothrottles. This manipulation was included to vary the flightcrew workload to see if changes in workload influenced pilot use of the information.

Procedure

The study took approximately three hours to complete. Flightcrews began with a 15-minute pre-flight briefing, followed by approximately two and a half hours in the simulator to complete the scenarios, and a 15-minute debrief. During the pre-flight briefing, flightcrews completed the informed consent form, received an overview of the flight deck concept as well as what to expect in the simulator, and completed a background questionnaire. As part of the overview, flightcrews were informed about the concepts of "concurrent use" and "differentiation." We specifically instructed pilots that the electronic chart information shown on the forward display was the same information (and same quality) as that shown on the portable electronic display and therefore, it was not intended for use for navigation. We also called pilots' attention to a header labeled "EFB" that was used to differentiate the electronic chart information from the approved navigation information.

Once in the simulator, flightcrews completed three practice scenarios using the new flight deck concept. This took approximately 35 minutes. As part of the practice scenario, flightcrews interacted with the electronic chart shown on the side display and repeated on the front display to familiarize themselves with the "mirroring" behavior. This mirroring capability allowed the pilot to interact (e.g., pan or zoom) via touch on one display and have the action reflect on both displays.

Following the practice trial, flightcrews completed eight scenarios. Flightcrews flew two scenarios—one approach and one departure—in each condition (i.e., each cell as shown in Table 1). Prior to the start of each scenario, the flightcrew was told whether they were flying an approach or departure, what chart to load, and whether they would by flying the scenario manually or with the autopilot. Flightcrews could take a break at any time but were specifically offered a break after the fifth scenario.

Each flightcrew member completed an electronic post-condition questionnaire to gather subjective data about the use of the electronic chart and general usability issues. At the end of the study, each flightcrew member also participated in a post-test interview to gather overall impressions regarding the new flight deck concept.

RESULTS

Our data set for this study focused on the subjective perceptions of the new flight deck concept. In general, flightcrews indicated that they used the electronic chart information and that this information was easy to use, regardless of display location or workload. As shown in Figure 2, First Officers indicated that they used the electronic chart "very often" (56%), whereas Captains' ratings fell between "often" (35%) and "sometimes" (38%). The ratings are likely due to their different responsibilities; the Captain was tasked with flying the aircraft whereas the First Officer was responsible for monitoring the progress of the aircraft.

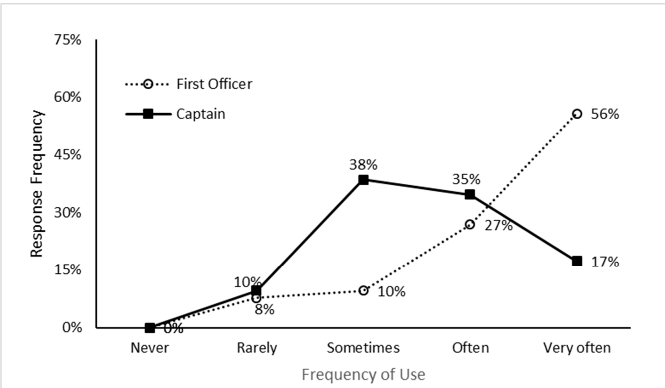

Figure 2. Perceived frequency of use.

Both First Officers and Captains felt that the electronic chart was easier to use when it was shown on the front display than on the side; this is shown in Figure 3.

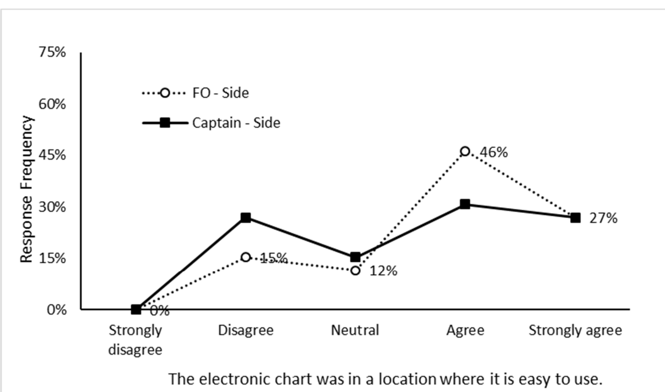

Figure 3. Ease of use (display location).

We asked flightcrews whether the location of the electronic chart information changed their scan pattern. Most indicated that their scan pattern did not change when the electronic chart information was shown on the side display but did change—in a positive way—when that information was shown concurrently on the forward panel. In particular, several flightcrews indicated that they felt their instrument scan was more efficient when the electronic chart was shown on the front panel than on the side because it felt like the length and direction of the scan was reduced (compared to when the electronic chart was shown on the side display). One pilot stated that once he incorporated the new concept into his scan pattern, the electronic chart information "gives me a sense of direction… [provides a] quicker interpretation [when scanning instruments]." Several pilots specifically indicated that they looked at the electronic chart information "a lot more" when it was shown forward than on the side, and one Captain said he never looked at the electronic chart information when it was presented on the side.

Flightcrews especially liked that the electronic chart information was repeated and "mirrored" on the side and center displays. In fact, one Captain noted that he could pan and/or zoom using the side display to manipulate what he/she was seeing on the center display without even looking at the side display. Flightcrews found panning and zooming with the electronic chart to be easier on the side display than on the center display because the side display was easier to reach. The portable display was located within arm's length whereas touching the front panel was typically more of a stretch. In fact, we noticed pilots interacting with the side display while looking at the front display. Thus, although pilots liked *seeing* the information on the front panel, they liked *controlling* the information from the side display.

The "cost" of displaying the electronic chart on the front panel, however, was that we reconfigured the primary flight display and navigation display information to fit into a smaller space. Pilots did not like reducing the size of this information; one pilot even commented, "I'm lost without the map here."

We wanted to understand if pilots differentiated the "uncertified" electronic chart information from the approved navigation information. We asked pilots if they noticed the border used to differentiate that information as well as whether they understood the border's meaning. Although we provided this information to flightcrews during the training briefing, we were interested in examining if flightcrews retained this information. Our results showed that all flightcrews noticed the header, although one flightcrew indicated that they would have missed it had we not called their attention to the header during the training. Ten of the 13 flightcrews remembered the meaning of the header after they completed all the scenarios. More interestingly, only seven flightcrews thought that the header was shown at all times. Four of the flightcrews did not think that the header was present all the time, and one Captain indicated he looked at the display but "didn't see it once." While the header was *always* presented, the subjective data suggests that this method of presentation may not be salient enough. It is also possible that some flightcrews became habituated to the presence of the header such that they no longer noticed it consciously.

Finally, we asked flightcrews if they noticed any errors in the depiction of ownship position. None were planned, but we unfortunately encountered issues with the global positioning system (GPS) device used to simulate aircraft position. Only some flightcrews specifically stated that the depiction of ownship position was incorrect at times, with one pilot stating that "obviously we will trust the ND."

CONCLUSIONS

This study provides pilot impressions for a new flight deck concept in which an electronic flight bag application (an electronic chart), which is not sufficient for navigation, is presented *concurrently* on an installed flight deck display and *differentiated* from approved navigation information. In our study, flightcrews generally liked the presentation of electronic chart information concurrently on *both* a portable electronic display off to the side and on the front panel with approved navigation information shown on the front panel only. Flightcrews felt that the forward location facilitated integration of the electronic chart information into their scan patterns. However, we observed a disadvantage of the forward presentation in terms of *interacting* with the information in the front panel because the front panel required pilots to reach to interact with the touch display. On the other hand, the portable electronic display on the pilot's side was closer and more easily accessible than the front panel. This "remote" control is similar to aircraft designs with controllers in the center console or side that is within reach of the pilot, so the pilots in our study were likely already used to interacting with the forward displays through a remotely located controller. As a result, we saw benefits for the mirroring functionality, which allowed pilots to make control inputs using the portable electronic device on the side and have these actions reflect on both the front and side displays. We did not include a condition without mirroring, so we do not know how a similar concept without mirroring would be received. However, the data does suggest that touch interactions using a forward display as the main form of interaction should be carefully evaluated.

Our attempt at *differentiation* was only moderately successful. The data suggest that our method of differentiation with a header was initially salient, but one-third of the flightcrews in our study did not recall whether the border was present through all the scenarios. Differentiation is an important component of AC 120-76D, so the issue of stimulus habituation should be considered when examining the operational use of these concepts.

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