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OPTIMIZING EFB USE THROUGH TRAINING, STANDARDS, AND BEST PRACTICES

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The Electronic Flight Bag (EFB) provides an integrated information management system that promises new capabilities and benefits to pilots, but information access and display differs substantially from traditional paper documents. Pilots must understand what information is available and where it is located, how data is accessed and entered, and how this system interacts with other aircraft systems. Operators must develop standards, best practices and training that will optimize the EFB capabilities and ensure safe and effective crew performance. This paper presents how key training and procedural enhancements as well as the identification of best practices can be identified during the EFB operational evaluation for incorporation into ongoing line operations.

Introduction

The paperless cockpit has been a longtime promise of the Electronic Flight Bag (EFB). In general, it provides an enhanced information system with many benefits such as efficiency, improved safety, reduced costs, and lighter flight bags. However, in that transition to an electronic system there are numerous design decisions and costs that must be addressed. Issues such as risk mitigation and the establishment of backup systems, new security issues and responsibilities, and the implementation of a new revision process need to be resolved. Clearly "paperless" is not likely to be total and every variation of hybrid paper and electronic system will have slightly different considerations. The EFB discussed in this paper consists of flight operating documents including navigation charts, Minimum Equipment List and others, but still requires paper documents outside the EFB system such as Maintenance Log, Quick Reference Handbook and Checklists.

Certification Requirements

In addition to many potential varieties of EFB, there are major classes. Class 1 EFBs (portable standalone computers) have been in operation for many years, but the Class 2 EFB, which is the topic of this paper, is still in the beginning stages of certification and implementation. While generally COTS-based and portable like the Class 1 computers, Class 2 EFBs are connected to an aircraft mounting device with power and data connectivity and require an administrative control process to be added, removed, or used in the aircraft. Certification requirements are still evolving, but current guidance is primarily Advisory Circular 120.76A, Guidelines for the Certification, Airworthiness, and Operational Approval of Electronic Flight Bag Computing Devices (FAA, 2003). AC 120-76A is supplemented by more detailed guidance for FAA inspectors (see Chandra, Yeh & Riley, 2004, Chandra & Yeh, 2006) and Job Aid: Electronic Flight Bag Evaluation and Approval, Version 2.0 (FAA, 2006). Current guidance differentiates among hardware, software and operational requirements, each with its primary relevance to human factors. For instance, hardware requirements focus on non-interference with aircraft systems, egress, and usability while software requirements focus on crew workload, integration across applications, and human/machine interface.

EFB Operational Evaluation

Operational requirements involve hardware and software with emphasis on crew performance using the integrated EFB system in the context of operational conditions and procedural compliance. Crew performance must be demonstrated to be at least as safe as current operations with paper systems. In order to satisfy the operational approval requirements, a comprehensive EFB evaluation plan was developed including the evaluation of EFB prototypes prior to the operational evaluation of the final Phase 1 version of the EFB. In order to demonstrate that operating the EFB document system would be comparable or better than the current paper document system, a simulator experiment was designed to systematically compare crews using Electronic documents and crews using Paper documents in a carefully controlled Line Operational Evaluation (LOE) scenario across all phases of flight. Performance measures, as well as training observations, video recordings of the flight performance and screenshots from the EFB provided a rich set of data for assessing crews EFB use in line operations. The results provide insights into the ways in which standards, training, and best practices can optimize EFB use by pilots.

Methods

Participants

The Operational Evaluation enlisted 20 volunteer crews, 20 Captains (CA) and 20 First Officers (FO) from the fleet transitioning to the EFB. On the average, these experienced pilots had 7,458 total flight hours and 1,359 flight hours on fleet type. Four subject matter experts from the company were assigned to be the Instructor/Evaluators (I/Es) for the Operational Evaluation fully participating in the development of training and standards and the LOE scenario in addition to conducting the crew training and LOE evaluation.

Crew Training

Prior to a LOE, all crews were given about 5 hours of training including home study materials, classroom instruction, practice time, and a simulation briefing as shown in Table 1.

Table 1. Training for the Operational Evaluation

EFB and Charts Home Study
Home Study Outline and Instructions (5 min)
Charts Training Document (60 min) • Introduction to new charts, new information, location of information • Introduction to differences: symbology, abbreviations, chart characteristics Aircraft Flight Manual Bulletin (30 min) • Operation of the hardware: ON/OFF, brightness control, battery power • Operation of Charts application: setup, chart access, day/night modes • EFB functions: Print, Load, Sync, Send • Automation Philosophy • EFB preflight (CA, FO) • EFB failure procedures
Website Operations (30 min)
Document Review (30 min)
Open book Home Study quiz (15 min)
EFB and Charts Classroom Briefing
Introduction to the study, its objectives and an outline of the session (7 min)
EFB hardware overview (3 min)
Charts setup (55 min)
Utilization of EFB and contingencies (15 min)
Practice (15 min)
Classroom quiz (15 min)

In the EFB and Charts Home Study, standards and EFB Standard Operating Procedures (SOP) were presented through a new EFB Aircraft Flight Manual Bulletin. The Bulletin explained that the EFB provides navigation charts and information to validate FMS data and enhance situational awareness. During taxi, situational awareness would be enhanced by the graphic presentations of the airport layout corresponding with progressive taxi requirements. A section on EFB failure discussed backup requirements and various alternate information sources to be used in the event of EFB system malfunction (e.g., use of print function with the off side EFB, ATC). Finally, flight phase-specific restrictions on EFB programming for Pilot Flying and Pilot Monitoring were provided as specific guidance supporting the Automation Philosophy.

> . . . *EFB programming should be accomplished in a non-critical phase of flight to the maximum extent practical. . . Programming accomplished due to a route change or change in destination must not distract from basic aircraft control or clearance compliance. . .*

For example, during Before Start, both pilots may use any available functions of the EFB. In contrast, during Climb, the Pilot Flying is limited to chart selection from pre-selected charts and dragging the chart for optimal viewing. The SOP specifies that other EFB operations are to be made by the Pilot Monitoring.

In the 2-hour EFB and Charts Classroom Briefing pilots had their first opportunity to practice the EFB functions as the Instructor covered the topics shown in Table 1. The section on Utilization of EFB and Contingencies reviewed the flight phase specific restrictions on EFB programming, and the available options for obtaining navigational information when an EFB failed. Again, pilots were reminded to guard against allowing the EFB display or functions to consume the attention of both pilots while the aircraft was moving.

Instructor/Evaluator Training

To ensure consistent performance evaluations, four I/Es were trained and evaluated according to an Inter-Rater Reliability (IRR) method described by Schultz, Seamster and Edens (1997) and Williams, Holt and Boehm-Davis (1997).

The IRR process was begun early in order to correct rating biases, and to collect baseline measures of crew performance under the existing paper document system. A final IRR check was designed based on Holt, Hansberger, and Boehm-Davis (2002). To assess reliability, the I/Es were asked to evaluate pilot performance and head-down time for a single taped crew performance on the LOE described in the next section.

LOE Scenario

The LOE scenario was developed to evaluate a crew's use of flight operating documents (whether paper or EFB) with an emphasis on navigation charts. Six event sets allowed for the evaluation of document/EFB use during Preflight, Engine Start, Cruise with several route changes, a divert, and a low visibility Taxi-In. Each event set was designed with a specified start and stop point so that I/Es could fully attend to each crew member evaluation in a systematic way. Captain (CA) and First Officer (FO) actions were evaluated separately thus providing performance assessments that were tied to event set- and role-specific behavioral markers (see Table 2).

Design

The Operational Evaluation was designed to compare the performance of one set of 10 crews randomly assigned to working with their current paper flight deck documents with a second set of 10 crews working with the EFB document system. Instructor/evaluators were assigned to the crews ensuring that each conducted both EFB and Paper assessments. During the LOE session (approximately 3 hours), data collected included crew performance ratings, crew workload ratings, videotape records and EFB screen shots. A debriefing gave participants the opportunity to provide feedback about the EFB training and LOE experience.

Table 2. LOE Event Set Performance Ratings that Applied to both CA and FO

ES1 FMS	CA use of nav pubs to reload and verify FMS FO use of nav pubs to verify FMS load during brief
ES1 Briefing	CA use of FMS and nav pubs to conduct brief FO pre-flight use of nav pubs before and after brief
ES2 MEL	CA managing use of MEL FO use of MEL
ES2 Resolu-tion	CA use of resources to make decision to disconnect DRIVE 1 FO support of problem resolution
ES3 SOP	CA compliance in use of nav pubs to identify new airway FO SOP compliance in use of nav pubs to identify new airway
ES3 FMS	CA update or verify FMS FO update or verify FMS
ES4 SOP	CA compliance with Approach Brief FO compliance with Approach Brief
ES6 Taxi	CA use of nav pubs prior to and during taxi FO use of nav pubs prior to and during taxi
ES6 SOP	CA taxi SOP FO support of taxi SOP

Results

LOE Crew Performance Results

More detailed description of the Crew Performance results are presented in (Seamster & Kanki, 2007), but selected highlights are mentioned here. Nine of the crew performance ratings were conducted for both the Captain and First Officer and their means are shown in Figure 1. All nine items show better performance for the crews working with the EFB, but three ratings in Event Sets 3, 4, 6 (highlighted inside boxes) are significantly better

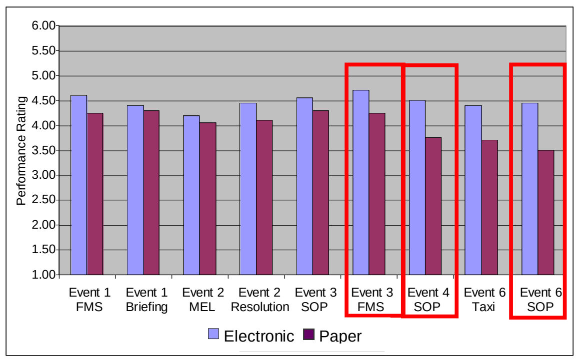

Figure 1. Mean Crew Performance ratings for Electronic versus Paper Documents by Event Set (significant differences, $p < .05$, highlighted)

The mean rated Head-Down Time from Minimal to Excessive are shown in Figure 2. Although Head-Down Time is less for crews working with EFB versus crews working with Paper across all Event Sets, the differences in the four event sets highlighted inside boxes are statistically significant.

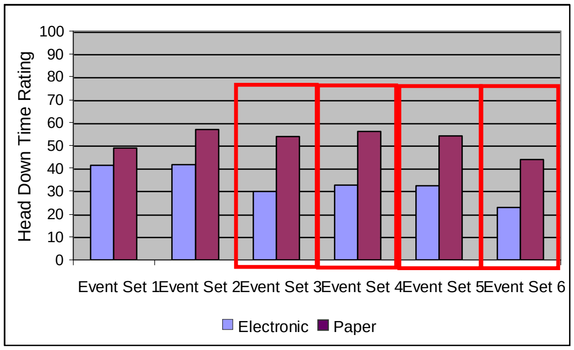

Figure 2. Mean Head-Down Time ratings for Electronic versus Paper documents by Event Set (significant differences, $p < .05$, highlighted).

Workload was rated by each pilot immediately following the LOE using a NASA TLX-based questionnaire for each event set (see Hart & Staveland, 1988). Twenty six of the workload items rated showed no significant difference between pilots flying with EFB or with Paper documents. The ten items that were significantly different are shown in Figure 3. All but one of those items (circled), Event Set 1 "How rushed was the pace of the PreFlight?," showed significantly lower workload or higher success for EFB crews compared with Paper crews.

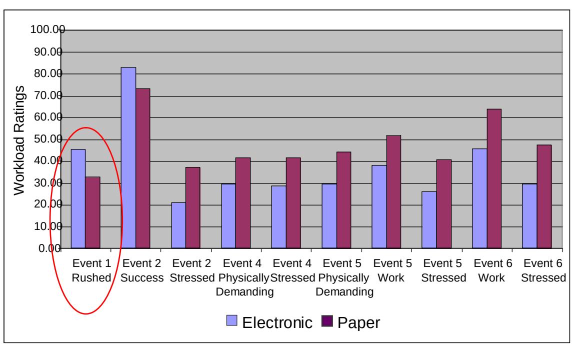

Figure 3. Significantly reduced ($p < .05$) Mean Workload ratings for Electronic versus Paper documents (exception in Event Set 1 circled).

Implications for Training

Implications for EFB training are based on a number of data sources: crew feedback, training observations, and performance measures. Because some of the training implications were specific to the particular EFB system under evaluation, those implications were reworded to apply to a more general class of EFBs.

As mentioned earlier, Home Study was used to introduce the EFB system. Pilots learned basic information about the hardware and software applications as well as EFB procedures and Automation Philosophy. The Classroom Briefing was the first opportunity to practice using the EFB applications on a computer. Key EFB hardware recommendations based on crew feedback and training observations include:

- Provide specific instructions on use of finger touch vs. stylus
- Instruct drag vs. scroll and pan
- Provide tips to reduce number of touches.

Although pilots may develop preferences for how they use the EFB hardware, initial training could provide specific instructions on how best to handle the EFB and its touch screen.

Recommendations regarding EFB software applications included:

- Provide a clear distinction between Menu functions and how to select charts
- Provide an overview of color coding
- Identify key symbology differences
- Develop a chart that reviews key item placement possibly by phase of flight
- Explain naming and meaning of EFB buttons
- Note the addition of new information on charts.

Since the EFB charting application utilized navigation charts that were different from the traditional paper charts, a 2-part approach to training could be developed. When introducing new formats on the EFB, operators should consider first introducing the similarities along with the general overall coding and symbology scheme. Then, the training can delve into the specific differences grouped in ways that are easiest to learn.

More time to practice and explore the EFB functions would further improve pilot performance. The development of more practice opportunities with realistic contingencies would be useful. This would be enhanced by the development of practice session examples, Chart selection examples and practice tests that are regularly updated. Answers with explanations should always accompany tests so that errors can be understood and corrected. Finally, as the training materials are developed, quality reviews for consistent terminology, definitions and concepts should be conducted.

It was evident from the LOE performance results as well as videotape records that some of the EFB crews were developing best practices that could be helpful to others. For instance, some crews demonstrated coordination strategies for workload distribution and reduction of Head-Down time. These types of behaviors are more easily demonstrated by video than described in words alone. Thus the consideration of visual media to illustrate flows and other best practices may prove to be an effective supplement to documents and individual practice.

Implications for Standards

The Performance Ratings, Head-Down Time and Workload Ratings showed that EFB crews performed better with respect to procedures and the Automation Philosophy. Performance ratings were better for EFB crews across all events sets and significantly better in Events Sets 3, 4 and 6. As shown in Table 3, the behavioral markers for these Event Sets are all procedural in nature, pertaining to FMS verification procedures, and compliance with Approach Brief and taxi SOP.

Event Set 3 follows taxi, takeoff and climb with an Air Traffic Control (ATC) clearance amendment to join a specific airway. EFB crews showed improved compliance in use of navigation publications including enroute charts in making the airway change and subsequent updating and verifying of the FMS. In Event Set 4, ATC has just issued a clearance change. Crews must update the FMS and use navigation publications in order to conduct the Approach Brief. EFB crews show improved compliance with the Approach Brief. In Event Set 6, the crew has been issued initial taxi instructions in a low visibility environment and must use navigation publications to comply with the taxi instructions. For EFB crews, the Captain's EFB is failed after a turn on to a taxiway. EFB crews showed more effective use of approach and airport charts prior to and during low-visibility taxi, and subsequent improved taxi SOP by the CA (with failed EFB) and support of taxi SOP by FO.

Table 3. Behavioral Markers for Significantly "Better" EFB Crew Performance Ratings

ES3 FMS	CA update or verify FMS FO update or verify FMS
ES4 SOP	CA compliance with Approach Brief FO compliance with Approach Brief
ES6 SOP	CA taxi SOP FO support of taxi SOP

The Head-Down Time results (Figure 2) also showed better performance by the crews working with the EFB as they had less Head-Down Time for all event sets (and significantly less in Event Sets 3, 4, 5 and 6). As such these results are consistent with the Automation Philosophy because these are flight phases in which aircraft control and clearance compliance are critical. Even though frequent use of navigation publications, FMS updating and verification encourage Head-Down activity, the video data showed that the best EFB crews achieved effective division of labor with the Pilot Monitoring (PM) engaged in most of the Head-Down activities while the Pilot Flying (PF) did not. This was usually accompanied by the PM identifying the relevant charts and transmitting them to the PF's EFB.

Crew feedback indicated that pilots felt that the EFB would reduce workload and the Workload Ratings largely supported this. As shown in Figure 3, EFB crews rated less workload across Events 2, 4, 5 and 6. The exception was Event Set 1 during which EFB crew rated themselves as more rushed during Preflight. While this may suggest a need for more training time for Preflight EFB usage, it is encouraging to see reduced workload ratings during the challenging flight phases in which several route changes, a divert, and a low visibility Taxi-In were required.

The operator's standards supported the EFB procedures and philosophy especially in the later phases of flight. To further optimize EFB standards and SOP, operators should consider:

- Fully integrated EFB SOP (e.g., verification of FMS) with the training of EFB functions (e.g., accessing new charts after a clearance change)
- More detailed description of how EFB reduces workload and head-down time by phase of flight
- Procedures for addressing the full range of EFB failures.

In addition, procedural guidance pertaining to EFB support functions includes:

- Procedures for checking data currency
- Procedures that establish crew versus maintenance responsibilities
- Procedures relating to data security.

Implications for Best Practices

This operational evaluation identified some major gains in EFB effectiveness in the area of Best Practices. Most of the following recommendations are based on training observations and observations made from the videotape and screenshot data collected during the LOE. By conducting a detailed comparison of 2 of the highest performing EFB crews with 2 of the lower performing EFB crews, we could identify both individual and team behaviors that highlighted efficient EFB use. Among the best team practices observed were the following:

- A consistent way of coordinating FMS and EFB updating, followed by cross-checking EFB and FMS during Preflight and Flight was established
- Programming duties were delegated explicitly, using the EFB SEND and SYNC functions to avoid duplication of effort
- EFB charts were used to support departure and arrival briefings
- EFB charts were used to coach taxi navigation
- During EFB failure, PRINT function was used.

In addition, the following team and individual Best Practices recommendations could be made:

- Develop Preflight Best Practices or Flows.
- Develop Best Practices for coordination of Pilot Flying / Pilot Monitoring roles
- Specify how EFB supports FMS programming and verification
- Specify Best Practices for EFB viewing, data entry, chart access
- Specify Best Practices for verifying correct chart selection (e.g., checking chart labels).

Since training for the flight crews was compressed during the Operational Evaluation, there was limited time to gain familiarity with various EFB functions and little opportunity for crews to consider the effects of operational pressures or non-normal conditions. In spite of these constraints, EFB SOP and training produced positive results in crew performance. These recommendations represent refinements that can help to optimize EFB use. The Operational Evaluation paves the way for initial EFB implementation, and the data collected provide invaluable information for understanding how best to integrate the EFB system into line operations.

Acknowledgments

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