REVIEW OF SAFETY REPORTS INVOLVING ELECTRONIC FLIGHT BAGS

Divya C. Chandra and Andrew Kendra
United States Department of Transportation
John A. Volpe National Transportation Systems Center
Cambridge, MA

Electronic Flight Bags (EFBs) are a relatively new device used by pilots. Even so, 37 safety-related events involving EFBs were identified from the public online Aviation Safety Reporting System (ASRS) database as of June 2008. In addition, two accident reports from the National Transportation Safety Board (NTSB) cite EFB as a contributing factor. Underlying EFB issues were ascribed to each ASRS report by the authors based on subject matter expertise. Pilots reported issues such as configuration of the chart display and difficulty using the EFB when they were newly implemented. Both NTSB reports identified use of an EFB for calculation of landing distance as a contributing factor in the accidents. The NTSB reports identify areas for improvement in the evaluation of EFB software as well as training and procedures. This report provides further recommendations for improving EFB guidance materials to mitigate safety issues.

The Electronic Flight Bag (EFB) industry has grown rapidly since the Federal Aviation Administration (FAA) issued Advisory Circular (AC) 120-76A in March of 2003 (FAA, 2003). A recent review of EFB products shows the diversity of implementations that are being purchased and deployed by all types of operators (Yeh and Chandra, 2007). Their benefits include better access to aircraft operating documents, just-in-time flight performance calculations by the flight crew, and reduction of paper charts and documents in the flight deck. For more information on what functions EFBs support, see Shamo (2000) and Hirschman (2009).

The purpose of this report is to examine what, if any, safety impacts EFBs are having as the industry matures and units are deployed more widely. To accomplish this task, safety-related reports pertaining to EFBs were obtained from the public online Aviation Safety Reporting System (ASRS) database managed by the National Aeronautics and Space Administration (NASA). These reports were analyzed to understand what impact the EFB had in the event. In addition, we review two National Transportation Safety Board (NTSB) reports that cite the EFB as a contributing factor in aircraft accidents.

ASRS reports are useful for identifying human factors areas of interest. However, there are limitations to the data. In particular, these are subjective self-reports that were submitted voluntarily. The reporters are not trained observers and may have difficulty in observing their own situation and performance. Also, the ASRS website states that in many cases, the reports have not been corroborated by the FAA or NTSB and therefore the report database cannot be used to infer the prevalence of a particular problem within the National Airspace System.

In this report, we discuss how the EFB-related reports were identified and then describe the overall set of reports that were obtained. We present descriptive observations about the data, interpret the safety reports to determine what EFB human factors issues were encountered, and summarize the EFB-specific issues from the NTSB reports. We conclude with recommendations for improving guidance to mitigate these issues.

Identifying EFB-Related Safety Reports

Safety reports were collected from the online ASRS database in June 2008 (http://asrs.arc.nasa.gov). The NTSB reports were obtained from the online database (http://www.ntsb.gov). Other databases that may contain EFB-related safety reports, such as those kept by airlines, are not publicly accessible and were not searched.

In order to find EFB-related reports in the ASRS database, a key word search was conducted on the full narrative and synopsis of the report. This task was complicated because there is no standard terminology in use for EFB systems and applications. The following search terms were used to identify the relevant reports: *EFB*, *Onboard Performance Computer*, *Tablet PC*, *Tablet*, *Paperless*, *Electronic Chart*, *Laptop,* and *APLC* (an abbreviation used at one airline for “Airport Performance Laptop Computer”). In order to locate the more recent accident report on the NTSB website, the term “Onboard Performance Computer” (OPC) was used. The resulting accident report, from 2007, references an older report from 2000 in which the EFB is referred to as the APLC.

Spurious reports were often returned from the ASRS search and these were manually removed from the search results. In some cases the unrelated reports were easily identified, such as references to passenger laptops or medicinal tablets, but other reports were reviewed carefully to determine whether the EFB was actually a factor in the situation. Cases where the EFB was used normally during incidents that were set in motion by other factors were not considered relevant. For example, if a report mentioned that the first officer was using the EFB, then stowed it to listen to air traffic control communications, then no problem with the EFB was documented per se, and the case was dropped from the set. Other cases were excluded for a variety of reasons. For example, in one case, a Part 91 operator's laptop-based moving map display failed to function at a critical time. This case was eventually discarded because Part 91 moving map displays are not addressed under AC 120-76A (FAA, 2003) and because this type of map display is similar to hand-held or installed GPS displays, which are generally not classified as EFBs.

Analysis

Some information was copied directly from the ASRS report into a spreadsheet for analysis, but other information was constructed by the authors based on their subject matter expertise. For example, the authors classified the outcome or anomaly that occurred and judged whether the EFB was a primary or contributing cause for the outcome or anomaly. Table 1 shows what information was copied, extracted, or interpreted about each event.

Table 1. *Information extracted or constructed for each relevant safety report.*

Information Copied Directly From ASRS Report	Information Extracted or Interpreted from ASRS Report	Interpretations of the Event Constructed by Authors
• Case Number • Year • Operating Regulation (e.g., Part 91) • Operator Type (e.g., Corporate) • Synopsis • Callback Interview • Flight Conditions (e.g., visual or instrument) • Light (e.g., nighttime, daytime) • Other Environmental Conditions • Aircraft Make/Model	• Relevant airport (e.g., origin, destination) • Phase of flight (e.g., arrival, climb) • EFB application in use (e.g., electronic charts) • Outcome/Anomaly (e.g., altitude deviation) • Interesting quotes • Search term(s) used to find the report • Description of EFBs in use (e.g., how many, what type)	• Summarized the EFB issue • Categorized the EFB issue • Determined whether the EFB was a *primary* or *contributing* factor to the outcome/anomaly.

In order to identify the outcome or anomaly, the authors tried to determine why the reporter considered the event as being serious enough to warrant filing an ASRS report. In general, the answer to this question was the "outcome." The outcomes and anomalies found in the ASRS reports are typically an actual violation or a "near violation" (i.e., a violation that almost occurred) of a requirement such as an altitude clearance, or published heading for a departure or arrival procedure. Filing a voluntary ASRS report grants the reporter a level of immunity for the violation as detailed in Advisory Circular (AC) 00-46D (FAA, 1997). There was only one such outcome/anomaly in each of the reports.

In order to distinguish between primary and contributing factors for the event, we reviewed the reporter's narrative carefully to determine the order of events and the self-reported actions and difficulties. The primary factor was the one without which the event was likely not to have occurred at all. Contributing factors tended to complicate or exacerbate the situation. In some cases, the narrative clearly identifies what the reporter considered to be the primary factor in the event or there was only one factor in the event (e.g., an expired database on the EFB). In most cases, however, there was more than one factor and the authors attempted to prioritize the factors. The use of these terms, "primary" and "contributing" factors, is consistent with language used in NTSB reports.

In addition, the description and classification of the EFB issue encountered was based on the authors' judgment. This was the most subjective part of the analysis. In some cases there was enough information to judge what the issue was with regard to the EFB (e.g., the reporter mentioned that he/she was unable to read the screen in bright sunlight). In other cases there was not enough information to identify the exact problem. For example, if there were difficulties accessing information, it may have been because there was a software bug, or because the user training was insufficient, or because the EFB design was problematic. Here the EFB issue was classified more generally, to acknowledge that the underlying issue may not be well understood.

Another subjective aspect of the analysis was in determining the list of relevant EFB issues. The final list presented here was constructed iteratively; where there were enough similar cases, the issue was called out on its own, but if the events were relatively unique, they were placed in a "Miscellaneous EFB Operation" category.

Results and Discussion

Thirty-seven relevant reports were identified from the ASRS database. Descriptive statistics about these events are presented first for the information copied directly from the ASRS reports. Next is a discussion of the incident interpretations and the EFB issues that were encountered. A brief description of the two accident reports from the NTSB involving EFBs is provided after a discussion of ASRS events.

EFB-Related ASRS Events

Relatively few EFB-related ASRS reports were filed each year from 1995 through 2005 (zero to five events each year) but many more reports, 13 of the 37, were filed in 2006. The increased number of reports in 2006 may reflect the fact that EFBs were implemented more widely in the recent past. All types of operators are represented in the reports, but air carriers were involved in a relatively low proportion of the reports, just nine of the 37. More recent reports are largely from corporate operators. This may reflect the fact that while a small number of air carriers have been using EFBs for many years recent purchases have largely been from corporate operators. Weather and ambient lighting conditions do not appear to play a part in EFB-related safety reports. Most of the events (33) occurred in visual flight conditions. Reports were filed for both day (24) and night (8) conditions.

Eighteen of the 37 events occurred on departure. Twelve of these occurred during initial climb out, an especially busy time in the flight. Three events that occurred preflight (on the ground) were related to errors in computing weight and balance or flight performance and in two events the problem was an expired database.

Many pilots reported problems using the charts during the approach phase. The charting application was in use for 28 of the 37 reports. Note that the more recent reports tend to be related to the charts application, while older reports tend to be related to the flight performance calculations function. This also reflects the market trend that corporate operators, who purchased EFBs more recently, use them primarily for the charting function, while air carrier users, who purchased EFBs some time ago, use them primarily for flight calculations.

Four of the reports were filed for events that occurred while flying the same location and procedure, specifically, the Teterboro, New Jersey (TEB) departure procedure known as the TEB 5 departure. This procedure provides separation between departures from Teterboro and arrivals into Newark International Airport, which serves the New York and New Jersey metropolitan area. The TEB 5 departure is a complex procedure that imposes a high level of workload regardless of whether an EFB is used or not because there is little margin for pilot error (see NASA, 2007 and FAA, 2008b). We cannot determine whether the use of an EFB is an *additional* risk factor under these high workload conditions without more information than is available in the ASRS report.

Table 2 below provides a summary of the outcomes, and information about whether the EFB was a primary or contributing factor in the event. The most common outcome or anomaly was a deviation in track, heading, or speed; these occurred in 22 of the reports. A runway incursion occurred in four reports. However, the EFB was only a contributing factor, not the primary factor that caused the runway incursion in these four events. Other outcomes included incorrect weight and balance computations in three reports, use of expired databases, altitude confusion, deviation from a company policy, an aborted takeoff, and a tail strike upon rotation.

Table 2. *Outcomes and whether the EFB was a primary or contributing factor.*

Outcome	Total	EFB Primary Factor	EFB Contributing Factor
Spatial Deviation	22	12	10
Runway Incursion	4	—	4
Incorrect weight and balance computation	3	2	1
Expired database	2	2	—
Altitude confusion without violation	2	—	2
Deviation from company policy	1	—	1
Aborted takeoff	1	1	—
Incorrect take-off speed, tail strike on rotation	1	1	—
Altitude deviation during declared emergency	1	—	1
Total	**37**	**18**	**19**

The EFB was judged by the authors to be the primary cause for outcome in roughly half of the cases (18), and a contributing cause in the other half (19). Other factors for the outcomes in these reports included time pressure, fatigue, problems with the Flight Management Computer, and last minute changes to the aircraft clearance. Sometimes when the EFB was found to be a primary cause for the outcome, these other factors were also present as contributing causes. When the EFB was determined to be a contributing factor for the outcome, one of these other factors was typically the primary factor.

The EFB issues encountered in these reports are summarized in Table 3 below, along with examples and a list of related sections from Chandra, Yeh, Riley, and Mangold (2003), which is a primary resource document about EFB human factors considerations for the FAA and industry. Although Chandra et al. (2003) contains material that is related to the issues seen in the ASRS reports, that report does not necessarily address the specific situations that occurred. The purpose of the reference to Chandra et al. in Table 3 is to identify sections that could be updated by incorporating the issues encountered in the ASRS reports as examples. In particular, some of the EFB-related incidents cut across issues in Chandra et al. and the links between these topics could be illustrated more clearly. Note that the number of issues reported in Table 3 is greater than the total number of reports because more than one EFB issue was encountered in some of the reports.

Table 3. *EFB issues encountered, examples, and related references.*

Issue	Description	Cases	Related Section(s) from Chandra, et al. (2003)
Display Configuration	Related to zooming and panning to configure the display for readability. Information may be missed because it is out of view, or workload may be increased because of the task of configuring the display.	14	2.1.1 Workload 6.2.5 Zooming and Panning 6.2.11 De-cluttering and Display Configuration
New to EFB	The EFB is new to the crew.	10	2.1.1 Workload 2.3.3 Documentation for Part 91 operators
Miscellaneous EFB Operation Issues	EFB is difficult to use for a variety of reasons (e.g., stowed away, sluggish response in cold environment, big/heavy for the flight deck).	7	2.2.2 Stowage 2.2.3 Use of Unsecured EFB Systems 2.5.3 Display
Screen Legibility	Screen is hard to use under different lighting conditions.	5	2.1.5 Lighting-Legibility
EFB Inoperative	EFB or application is not available for use (e.g., EFB in sleep mode or rebooting).	3	2.4.5 Multitasking 2.4.9 Display of System Status
Chart Selection	Difficulty in selecting the required chart at the appropriate time (e.g., due to distraction, or turbulence).	3	6.2.6 Chart procedures 6.2.9 Access to Individual Charts
Software bug	Failure of the software to operate as expected.	3	No applicable section.
Flight Deck Procedures	Related to crew procedures for using the EFB(s) (e.g., sharing/cross-checking information).	2	2.3.1 Part 121, Part 125, and Part 135 Operations EFB Policy
Database Expired	Issue in maintenance or crew verification of database currency.	2	2.4.15 Ensuring Integrity of EFB Data 2.4.16 Updating EFB Data
Separated Information	Difficulty of accessing related information	2	2.4.18 Links to Related Material
Data entry	Difficulty with data entry function.	2	5.1.1 Default Values 5.1.2 Data-entry Screening and Error Messages

The EFB issue encountered most often in this set of ASRS reports was related to zooming and display configuration of electronic charts. In order to read detailed information on the chart the pilot has to zoom in, but in several events this resulted in the pilot missing important information that was off the screen. If the display is not zoomed in, small text can be misread. In addition, the display configuration tasks of zooming and scrolling create workload, and this workload contributed to pilot errors in some cases. One interesting comment from many of the reports was that the pilots would have preferred to have paper printouts of the charts for use during approaches and departures. Paper printouts at these times may be especially useful because hand-held EFBs must be stowed for safety during landing and takeoff (FAA, 2003).

The second most common EFB issue was that, in ten of the reports, pilots indicated that the EFB was a new device for them. This appeared to be a factor in the level of workload and pilot performance. Interestingly, of these ten reports, one was from a Part 121 carrier (from 1999) and one was from a chartered Part 121 flight (in 2007). All of the others were Part 91 or 135, either corporate, private, or charter flights. AC 120-76A (FAA, 2003) requires Part 121 operators to be trained on EFBs, but it does not apply to Part 91 operators. Requirements for Part 91 operators are more lenient (FAA, 2007) and they probably receive less training on EFBs than the Part 121 crews.

NTSB Accident Reports Involving EFBs

On July 31, 1997, a Federal Express (FedEx) MD-11 aircraft crashed while landing late at night in visual conditions at Newark International Airport in Newark, New Jersey (NTSB, 2000). Two crew members and three passengers escaped with minor injuries, but the aircraft was a total loss valued at $112 million. On December 8, 2005, Southwest Airlines (SWA) flight arriving from Baltimore ran off the departure end of runway 31C at Chicago Midway International Airport in Chicago, Illinois at nighttime in instrument meteorological conditions (NTSB, 2007). The Boeing 737-700 aircraft rolled through two fences and onto an adjacent roadway where it struck an automobile before coming to a stop. A child in the automobile was killed, and there were injured passengers both in the automobile and airplane.

The EFB was a contributing, not a primary, factor in both these events. Both accidents involved use of the EFB to calculate landing distance. The EFBs had been in use for some time at both SWA and FedEx and the accident crews were experienced with their use and related procedures.

In the FedEx accident, the NTSB found that the crew misinterpreted landing distances provided by the EFB such that they developed an unnecessary sense of urgency to touch down early and initiate maximum braking immediately. If the crew had correctly interpreted the EFB data, they would have known that there was actually an additional 900-ft stopping margin in the calculation. In response to NTSB recommendations from this accident, the FAA issued Flight Standards Information Bulletin for Air Transportation 02-03, which has since been updated to the InFO Safety Bulletin 0831 (FAA, 2008a). The bulletin reminds inspectors to review and ensure adequacy of training and procedures regarding use of EFB and interpretation of the data generated, including landing distance data.

In the SWA accident, the programming and design of the Onboard Performance Computer (OPC) was a factor. The OPC did not show two inherent assumptions that were critical to the pilot's decision to land. First, the pilots assumed that landing distance calculations were based on the value they entered for the tailwind component (8-knot), but the software actually showed landing distance based on a 5-knot limit for poor runway conditions allowed by company policy. The software highlighted the entered (8-knot) tailwind component on the display without indicating that the stopping margin was not based on that entry. Second, the OPC calculations incorporated the use of reverse thrust for this model of aircraft, but not for two other models that the pilots flew interchangeably. The pilots of the accident aircraft believed that the stopping margins they were shown were conservative because they thought that the reverse thrust was not entered into the calculations, but in fact, there was no such margin. The airline's guidance to pilots on these differences has since been clarified.

The NTSB report on the SWA accident correctly points out that guidance in Chandra et al. (2003) states only that the output of the performance calculations should be displayed in a manner that is understood easily and accurately, and that users of the EFB should be aware of an assumptions upon which the flight performance calculations are based (Section 5.1.6 Use of Performance Calculation Output, Chandra et al, 2003). The NTSB report provides specific suggestions for expanding these recommendations to ensure that critical assumptions are presented as clearly on the EFB as they are on paper (NTSB, 2007, pp. 48-49).

Summary and Conclusions

In this review, 37 incident reports related to use of EFBs were identified from the online ASRS database. Two NTSB accident reports involving EFBs were also identified. Descriptive statistics were computed for the ASRS events, and the authors reviewed the events in order to understand the EFB issues that were encountered. The most common EFB issue encountered in the ASRS events was related to display configuration for using electronic charts. Another important issue appears to be related to the introduction of the EFB to new users. The two NTSB reports cite the EFB as a contributing factor in accidents where landing distance calculations were a factor, even though crews were experienced with the EFB. The reports emphasize the need for proper design of the flight performance calculation software for EFBs, and proper review of crew training and procedures for the use of the EFB.

The results of this research can be used by regulatory authorities such as the FAA to update human factors guidance for evaluating and approving EFBs (e.g., Chandra, et al. 2003). In addition, these results can be used by EFB operators to anticipate issues that need special consideration. EFB manufacturers and designers may also find this report informative.

References

Chandra, D. C., Yeh, M., Riley, V., & S.J. Mangold (2003). Human factors considerations in the design and evaluation of Electronic Flight Bags (EFBs), Version 2. (DOT-VNTSC-FAA-03-07.) USDOT Volpe Center: Cambridge, MA. Available online at http://www.volpe.dot.gov.

Federal Aviation Administration, Advisory Circular (AC) 00-46D, February 26, 1997. Aviation Safety Reporting Program.

Federal Aviation Administration, Advisory Circular (AC) 120-76A, March 17, 2003. Guidelines for the certification, airworthiness, and operational approval of electronic flight bag computing devices.

Federal Aviation Administration, Advisory Circular (AC) 91-78, July 20, 2007. Use of Class 1 or Class 2 Electronic Flight Bag (EFB).

Federal Aviation Administration (FAA) Information for Operators (InFO) 08031 on Weight and Balance Control Methods: Auxiliary Performance Computer (16 May 2008).

Federal Aviation Administration (FAA) Information for Operators (InFO) 08036 Teterboro, New Jersey, TEB-5 SID (3 June 2008).

Hirschman, D. (2009, February). Avionics: Electronic Flight Bags. *AOPA Pilot*, 52(2), 95-98.

National Aeronautics and Space Administration (NASA) Aviation Safety Reporting System Callback newsletter, No. 334, October 2007. High density airspace and traffic mix.

National Transportation Safety Board (2007). Runway Overrun and Collision, Southwest Airlines Flight 1248, Boeing 737-7H4, N471WN, Chicago Midway International Airport, Chicago, Illinois, December 8, 2005. Aircraft Accident Report NTSB/AAR-07/06, PB2007-910407).Washington, DC: Author.

National Transportation Safety Board (2000). Crash During Landing, Federal Express, Inc. McDonnell Douglas MD-11, N611FE Newark International Airport Newark, New Jersey, July 31, 1997. Aircraft Accident Report NTSB/AAR-00/02. Washington, DC: Author.

Shamo, M. (2000). What is an electronic flight bag, and what is it doing in my cockpit? *Proceedings of the International Conference on Human-Computer Interaction in Aeronautics.* Toulouse, France: Cépaduès-Éditions.

Yeh, M. and D.C. Chandra. (2007). Electronic Flight Bag (EFB): 2007 Industry Review. (DOT-VNTSC-FAA-07-04). USDOT Volpe Center: Cambridge, MA. Available online at www.volpe.dot.gov.

Acknowledgements

This paper was prepared by the Behavioral Safety Research and Development Division at the Volpe National Transportation Systems Center. It is based on a more comprehensive technical report in preparation. This research was completed with funding from the FAA Human Factors Research and Engineering Group (AJP-61) in support of the Aircraft Certification Service Avionics Branch (AIR-130) and the Technical Programs and Continued Airworthiness Branch (AIR-120). We thank the FAA program manager Tom McCloy and FAA technical sponsor Colleen Donovan for their assistance. Thanks also to Michelle Yeh and Stephen Popkin of the Volpe Center for feedback on this report. The views expressed herein are those of the authors and do not necessarily reflect the views of the Volpe National Transportation Systems Center, the Research and Innovative Technology Administration, or the United States Department of Transportation.