The Effect of Electronic Flight Bag Use on Pilot Performance during an Instrument Approach

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Abstract

For years, paper-based navigation aids have been an integral part of safely operating an aircraft. While these tools have served their purpose well, the technology to replace them with a more productive and efficient device may have arrived. Electronic Flight Bags (EFBs) have quickly become popular for both commercial and private use. This study analyzed the effect EFBs have on pilot performance in a single pilot environment by evaluating the performance of instrument rated pilots at a large southeastern flight school. The participants (N=14) were asked to complete two instrument approaches in a flight training device. One approach was executed using an Apple iPad® equipped with ForeFlight™ software (the EFB), while paper charts were utilized during the other approach. Deviations in altitude, heading, airspeed, and localizer course from instrument pilot practical test standards were recorded, as was the time taken for each participant to configure the approach. Statistical analysis was conducted to determine if a difference existed between the two methods. The results showed a statistically significant increase in every analyzed performance metric when using the EFB. A survey of participants' perceived workload during the approaches was also conducted, which revealed participants felt using the EFB decreased their workload.

Introduction

In an age of increasing information availability, pilots must manage enormous amounts of data while maintaining effective cockpit management. Checklists, operations specifications, approach plates, NOTAM's, dispatch releases, and enroute charts are just a few of the items that must be managed and utilized properly during a typical flight. These items have traditionally brought a great deal of paper and disorganization into the tight confines of the cockpit. This clutter can create problems when the pilot needs to access an item during a high workload flight segment. An Electronic Flight Bag (EFB) may present a solution to this issue. In general, an EFB is a device that is used to display information digitally instead of on paper. The FAA defines an EFB as, "An electronic display system intended primarily for flight deck use that includes the hardware and software needed to support an intended function," (Federal Aviation Administration [FAA], 2003, p. 2). EFBs have the potential to increase productivity, as well as produce cost savings for users. However, like all technological advancements, there are challenges to the widespread adoption of EFBs. As EFBs continue becoming more prevalent, there is a clear need for more research into how the use of these devices affect pilot performance in critical situations (Chandra, Yeh, Riley, & Mangold, 2003).

Until the possibility of using electronic displays to view information became a reality, the consequences of using paper-based products were not even considered. The costs from the paper material itself, the maintenance required to keep it up-to-date, the clutter and inefficiencies it creates in the cockpit, and the effects on aircraft performance were considered facts of life, as there was no other way to provide information. As electronic means of communicating and displaying information have become less expensive and more readily available, the negatives of physical paper use become more apparent.

Literature Review

The key to understanding the regulatory aspect of EFB use under today's regulations is Advisory Circular No. 120-76A Guidelines for the Certification, Airworthiness, and Operational Approval of Electronic Flight Bag Computing Devices. This AC is not regulatory in nature, but does provide guidelines for EFB use. Of particular note is that the AC maintains that the guidance it provides only applies to operators of large and turbine-powered aircraft, not to those operating under Part 91 (FAA, 2003). This AC further states that 14 CFR Part 91 operators "do not require any specific authorization for EFB operations, provided the EFB does not replace any system or equipment required by the regulations," (FAA, 2003, p. 1). This is noteworthy as it opens EFB use up to 14 CFR Part 91 operators without any real regulatory burden.

To operate aircraft effectively pilots require a number of written resources, and until recent times these written resources appeared on paper. The monetary costs associated with the use of paper are much larger than one might expect. Alaska Airlines estimated that in 2011 it printed over 2.4 million pages of paper just in aircraft manuals (Alaska Airlines, 2011). If one type of document for one airline requires that much paper, it is easy to see how the costs of printing alone can be very significant. Another cost due to the use of paper comes from the maintenance paper documents need in order to remain current. Not only does the use of paper cause unnecessary costs, but it can also create a lack of efficiency and productivity in the cockpit due to clutter. Yet another problem with the use of paper is the weight that is added to the aircraft. Alaska Airlines estimated each pilot was required to have anywhere from 25 to 50 pounds of paper documents with them for each flight, which equates to over $1.5 million dollars each year being spent in fuel costs due to the weight of this paper (Alaska Airlines, 2011).

Many alternatives to eliminate paper charts have been proposed, however the literature suggests drawbacks exist. Until recently, electronic solutions were too bulky, complicated, or unreliable to pose a serious alternative to the use of paper. Some devices proposed to alleviate the problems of paper are dedicated EFB devices, integrated units, and most recently, the iPad®. The idea of a dedicated EFB device has been on the market for several years with limited success. However, these dedicated EFBs have been bulky, complicated, expensive and unreliable (Hughes, 2009b). Many of these devices have used small laptops with pivoting screens and typically a full operating system, usually Microsoft Windows.

This design added a layer of complexity to devices designed to be used inflight. Additional problems identified were that the batteries on these devices had a short duration, and the devices gave off a tremendous amount of heat, which was especially noticed when used in a pilot's lap (Chandra, Yeh, Riley, & Mangold, 2003).

Another form of EFB that has been brought to market is the integrated EFB. These devices are built into the cockpit of aircraft with advanced avionics systems. The most common form of this implementation is seen in large commercial airliners. These devices provide the pilot with aeronautical charts, manuals, taxi diagrams, etc. on a device that is not removable from the cockpit and is usually interoperable with the aircraft avionics. The main benefit of the integrated type of system is the ability to blend seamlessly into the aircraft systems already in place, which can help streamline cockpit procedures. However, these integrated systems do not provide the pilot the ability to do preflight planning and calculations outside of the aircraft as portable EFB systems do, and are relatively expensive. At the time of this study, these systems have not been widely adopted due to the cost involved (Fontaine, 2011).

The newest entry to the field of EFBs is Apple's iPad®. This device, introduced in early 2010, has created an entire industry segment that did not exist previously. Its intuitive interface, small form factor, proven reliability, relatively low price, and outstanding battery life has drawn in consumers who did not even know they wanted a tablet until they saw it for the first time. The reason this is important to the discussion of EFBs is due to the large market this created. Because the device was not built specifically for aviation, it has the necessary sales volume to keep prices low, which means a lower barrier to entry for pilots. The iPad's®'s interface is intuitive for use in-flight, as a pilot simply touches something with which he wants to interact. This strips away the complicated layer of buttons and menus which added complexity to other devices. The success of the iPad® in general aviation has even caught the attention of business and commercial operators, with the iPad® now in use, or in testing for use, at both Part 135 and Part 121 carriers. It looks more and more likely that the iPad® and other consumer devices will be the future of EFBs (Miller, 2011). The problem with the iPad® is that while it is very stable, it is still a consumer grade system so there is some reluctance to adopt it as an official device for use during critical phases of flight (Alaska Airlines, 2011).

Benefits of using an EFB

One of the primary benefits of EFBs is their ability to increase the pilot's situational awareness (Flight Safety Foundation Editorial Staff, 2005). Many EFBs allow pilots to see their position on a digital version of the paper charts they have always used. This provides a perfect mix of familiarity with the old while adding the benefits of the new technology (Flight Safety Foundation Editorial Staff, 2005).

Another way that these devices provide situational awareness is the ability to display layered versions of conventional charts. This technology allows pilots to only show the information needed for that particular phase of flight. For example, pilots can activate layers that show only VORs, airways, airports with certain specifications, etc. This allows pilots to have less information to absorb and interpret which allows them to maintain situational awareness without information overload (Flight Safety Foundation Editorial Staff, 2005). When using paper, pilots must switch between checklists, navigational charts, and weather information multiple times. This is an invitation for distraction and for the pilot to become lost in all of the data (Flight Safety Foundation Editorial Staff, 2005). When using an EFB for this task, the pilot is able to change between these different pieces of data much more easily and efficiently, therefore increasing the level of safety (Allen, 2003). Of course, even when an EFB is utilized, switching between display screens is still a necessity.

Risks of EFB Use

One downside to the use of EFBs as the sole means of viewing critical in-flight information is the possibility of device failure. No matter how reliable electronic devices become, the possibility of equipment failure will always exist. Those that are against the adoption of EFBs bring up equipment failure as a potential catastrophic event. There are ways to mitigate this risk however, through carrying back up batteries, paper copies, or perhaps even back up devices (Flight Safety Foundation Editorial Staff, 2005). While the probability that one EFB could fail is small, the probability that two independent systems could fail at the same time is unlikely. This solution would allow the full benefits of the transition to EFBs be realized, while still maintaining a dependable contingency plan in case of failure. The only problem this introduces is the additional cost of two devices (Hughes, 2009a).

One significant risk that EFBs pose is the possibility of technology overload for pilots as the transition to EFBs begins, and before experience can be developed. Situational awareness, multitasking ability, precision, and workload management have all benefited from technology advancements such as VORs, DME, GPS and advanced avionics. These technologies have consequently made some pilots extremely dependent on technology. It is very easy for a pilot to get in an advanced aircraft and become complacent relative to when flying traditional aircraft (Flight Safety Foundation Editorial Staff, 2005).

As EFBs are developed and implemented, it will be important to take care not to make them too complex. Doing so would negate the benefits of increased situational awareness and better productivity in the cockpit. It is also important that training procedures for using EFBs be established to train pilots to keep scanning outside the aircraft and to not focus inside on the new displays (FAA, 2003). Pilots need to maintain the ability to operate without an EFB or on the backup device if the situation requires (Hughes, 2009a).

ForeFlight™

There are numerous providers of applications for flight planning, flight tracking, and flight chart situational awareness needs, including ForeFlight™, GlobalNavSource, Navtech, Garmin®, WingX™, ARINC and Jeppesen® (McKenna, 2012). The Jeppesen® application Mobile Flightdeck Pro has been embraced by air carriers, large business operators and military customers (McKenna, 2012), but ForeFlight™ was one of the first applications to be developed and it remains the most popular EFB application for 14 CFR Part 91 aviation operators (Appcrawler, 2015). ForeFlight™ is a company that was started in 2007 by a software engineer and a pilot to give pilots a mobile flight planning tool for the just introduced Apple iPhone. The first piece of software ForeFlight™ created was solely for gathering weather information. As the power of the new iPhone began to be realized, ForeFlight's™ programmers saw that the device could do much more than just gather simple information. They soon released ForeFlight™ Mobile. Today's current version of this software—ForeFlight™ Mobile v.4—sets the standard for what can be done with consumer grade tablets like the Apple iPad®. It allows a pilot to go from route planning, to certified weather and NOTAM briefings, to the needed in-flight charts and checklists all without ever leaving the application. It is, by far, the most popular aviation application on the iPad® (ForeFlight LLC, 2011).

Statement of the Problem

A review of research concerning EFBs shows that there have not been any performance-based implementation studies completed. There is a significant amount of information concerning EFBs in general, but nothing available regarding pilot performance during their use. Research also indicates that EFBs, in some form, are going to be a part of the aviation world in the future (McKenna, 2012). Before these devices become the new standard, the industry must trust that EFBs will provide reliable pilot performance of at least current levels. This study was conducted to determine the relationship between pilot performance during a relatively high workload period of flight and the use of an EFB versus paper charts, with the following research questions to be answered:

1. Does using charts and approach plates in electronic form on the iPad®, as opposed to on paper, effect pilot performance—as measured by conformance to heading, course, altitude and airspeed requirements, time to set up an approach, and selection of appropriate approach minimums—during rapidly changing flight situations?

2. Does the pilot's perceived workload increase or decrease when using an electronic form of the required material?

Methodology

To answer the above research questions, an experimental study was developed. The study used a Frasca 142 flight training device (FTD) and a scenario that required the pilot to access charts in a high workload, time sensitive environment. For the study, Apple's iPad® loaded with ForeFlight™ Mobile software was used as the EFB. The high workload environment in this study was the need to find, brief, and set up an instrument approach under instrument meteorological conditions. This particular scenario simulated a sudden change in the approach expected at a destination airport, not an uncommon event. The environment required pilots to divide their attention between flying the aircraft and preparing for the approach. During a time such as this, any improvements in situational awareness or effort required to ready the approach should be obvious in the performance metrics. Each pilot completed two very similar instrument approach scenarios, one using the EFB and one using paper charts. This allowed measurement of the performance of each participant in relation to deviations in airspeed, heading, altitude, and course, along with the time required to prepare for an instrument approach. A survey given at the end of the session was used to determine if pilots had a preference of chart viewing method, and their perception of how each method affected their performance and effectiveness in the cockpit.

Participants

The participants for this study were drawn from the commercial ground school class at a large southeastern university during the spring semester of 2012. The study was approved by the university's Institutional Review Board for human subject research. A prerequisite of the commercial class is that a student have an instrument rating, which was an important inclusion criterion. This prerequisite ensured that these participants were well versed in the basics required to set up and fly an instrument approach, and that all of the participants had approximately the same amount of instrument flight time. There were 14 students enrolled in the class, and all 14 agreed to participate in this study. All participants were white males of traditional college age.

Instruments

The flight training device (FTD) used for the study had conventional display instrumentation, and a Garmin® GNS430 GPS unit provided both communication and navigation radio tuners for tracking the localizer and glide slope courses. For this study, the FTD was configured as a single-engine fixed gear generic aircraft.

The scorecard used for this study was designed to allow the researcher to efficiently measure the deviations in altitude, heading, airspeed, and localizer course from instrument pilot practical test standards (PTS). To minimize the need to correctly identify the position of the analog needles of the FTD's instrumentation, the frequencies of these deviations were taken at intervals throughout the simulation rather than measuring the actual amount of deviation. These readings were recorded as either "Within PTS" or "Outside PTS". The specific parameters were: altitude +/- 100 feet, heading +/- 10 degrees, airspeed +/- 10 knots, and localizer course +/- 1 dot of deflection. A stopwatch was used to ensure that the same number of readings was taken at the correct times for each participant. The time taken for each participant to configure the approach was also recorded. Finally, whether the participant had identified the correct minimums for the specified approach was recorded.

The paper charts that were used for the study included a Tennessee/Kentucky Terminal Procedures book published by AeroNav. These AeroNav, or National Aeronautical

Charting Office (NACO) charts as they were once known, are still commonly used among general aviation pilots (Gibson, 2011). For the EFB, an Apple iPad® was used. This iPad® was a 32GB Verizon 3G unit. It was loaded with a current version of ForeFlight™ Mobile HD 4. All other programs were removed from the loaded applications section of the EFB before the study to eliminate interference. All of the required charts for the study were downloaded onto the unit so that internet access would not be required, just as would be done for a flight. The post-test written survey consisted of five questions to gauge how the participant viewed using both the paper charts and the iPad®, as well as to document their previous experience using any form of EFB. A combination of descriptive questions and those using a Likert scale were used.

Procedure

When the participants arrived for their session, they were briefed on what to expect, and were given a short tutorial on how to use the iPad®, the AeroNav procedures book, and the equipment in the FTD. They were instructed to only tune in the necessary frequencies and not to load the approaches in the Garmin® GNS 430 unit. This ensured that familiarization with the GNS 430 would not skew the results of the study. The participants were also told to only brief the name of the approach, the location, the missed approach instructions, and the minimums for the approach. Given that each participant was instrumented rated, no instruction on the actual interpretation of approach plates was provided. This was to ensure that the briefing period and setup procedure for each participant was standardized. Participants were also instructed to begin setting up the approach as soon as they were given an "Expect" instruction from Air Traffic Control (ATC), and to announce "done" as soon as the approach was set up and the briefing completed. The scenario for this study was that the participants were pilot in command of a single-engine aircraft cruising at 3,000 feet, at a speed of 110 knots indicated, and a heading of 270 degrees, approximately 15 miles southeast of KMEM. The weather for the FTD sessions included a ceiling of 200 feet overcast, one mile visibility, calm winds, and an altimeter of 29.92 inches of mercury. The researcher acted as Air Traffic Control throughout the session. Suggested power settings were given, but all of the participants had prior experience in the FTD due to their instrument training at the university. Each student flew the scenario twice, once with paper and once with the iPad®. The use of the iPad® or paper first was alternated with each participant so as to not skew the results due to familiarity with the scenario on the second time through the procedure.

Once the FTD was in the pre-set position and the participant indicated that they were ready to proceed, the FTD was activated and a stopwatch started. The participant was instructed to hold the assigned heading, airspeed, and altitude until further instructions were received from Air Traffic Control. The first data points were taken at the 0:05 second mark, and then again at 1:00, and were recorded as either within PTS for each indicated variable or outside of the PTS for these same variables. This time period allowed the participant to become settled and trim the aircraft as needed. At 1:00 the participant was told to expect either the Instrument Landing System (ILS) 36 left or ILS 36 right approach into Memphis International Airport and to turn to a heading of 290 degrees. The exact time that this occurred was noted so that the researcher could see how long it took the participant to set up the approach. From this point forward, data was collected at 20 second intervals, as the participant worked to find the correct approach using either paper or iPad®, and to get the approach ready to fly. At the appropriate point, the participant was instructed by ATC to turn to a heading of 330 degrees, and was given an approach clearance to intercept the ILS localizer. After the participant completed the briefing and announced that they were done, it was determined if they had announced the correct minimums for the correct approach, and the ending time was recorded. When the participant crossed the outer marker, the data recording portion of the session was ended, although the participants finished the approach procedure.

After the first session in the FTD, the device was reset to the preset starting position. Radio frequencies and course indicators were also reset to a non-biased position. The participant was given three minutes to rest between the two sessions. Once they indicated they were ready, the scenario was repeated using the alternate method of viewing charts. A different approach than was used for the first session was utilized for the second approach, although the Memphis airport was still used. For example, if the participant had been given the ILS 36R approach the first time, they were now told to expect the ILS 36C approach. This ensured that none of the frequencies or minimums would be the same. A slightly different vector of 300 degrees was also assigned by ATC so that the risk of familiarization was reduced. The data was collected the same way as the first session. Once the second session was complete in the FTD, the participant was allowed to exit, and was immediately instructed to fill out the short survey to measure their perceived workload using each chart viewing method.

Results

The data for the observed performance metrics of altitude, heading, airspeed, localizer course, and time to set up the approach was recorded, and means and standard deviations of this data can be seen in Table 1. The score for the altitude, heading, airspeed, and localizer course parameters were the percentage of observations during which the participant was within PTS when the observation was made. The time to set up the approach was the actual time in minutes the participants took from the end of their approach clearance until they announced the approach was configured. The performance measures were analyzed using two sample t-tests assuming unequal variances (N=14). It was found that there was a significant effect on pilot performance regarding each of the measured parameters, with the EFB performance being better than the paper chart performance in each case, as can also be seen in Table 1.

Table 1

Participant Mean Performance Parameters

Parameter	Paper Score* mean (std dev)	EFB Score mean (std dev)	t-statistic**
Altitude	53 (12)	76 (11)	t = 5.06
Heading	54 (13)	80 (10)	t = 5.49
Airspeed	57 (13)	73 (12)	t = 3.03
LOC course	44 (18)	83 (18)	t = 5.21
Time to set up approach	2.45 (.78)	3.92 (1.50)	t = 3.27

*The Paper Score is the percentage of observations during which the participant was within PTS when the observation was made
**Two tailed t-test critical value at p=.05 is 2.1604

As to the question of whether the pilot was able to determine the correct minimums for an approach, it was determined that the iPad® increased the likelihood that the minimums were correctly identified the first time. Only 36% of participants were able to identify the correct minimums on their first attempt using paper charts. In addition, when using paper charts, 29% of the participants attempted to use the wrong approach plate such as a Category II or Category III chart, or even a chart for the wrong runway. When using the iPad®, 100% of the participants correctly applied the appropriate minimums for the approach assigned on the first attempt.

Survey

Question 1 on the survey the pilots completed after their session in the FTD dealt with the participant's previous experiences with the use of EFBs, including the iPad®, before this study. A large majority of the participants (71%) had never used the iPad® as an EFB, or had used one only a few times (21%). Questions 2 and 3 of the survey asked the participants to rate the effectiveness of the iPad® and paper charts individually under high workload situations such as what they experienced during the FTD session. The difference in the effectiveness rating scores indicated that the iPad® was felt to be more effective, with the iPad® generating an average rating of 5.0, and the paper charts generating an average ranking of 2.64, on a scale of 1-5. Question 4 sought to determine how the participants would describe their perceived workload while using the paper charts versus the EFB. The question was phrased as "How would you say that your workload/stress level changed relative to the type of chart used?" The participants indicated that the iPad® significantly reduced stress levels and perceived workload, with 86% indicating the EFB was "much easier" and 14% indicating the EFB was "somewhat easier." Finally, question 5 of the post-session survey sought to determine the participant's opinion regarding which method they would prefer. The question was posed as "If you were to find yourself in a rapidly changing situation during a flight, which form of chart would allow you to best handle the situation at hand?" The EFB was strongly favored by the participants, with 93% of participants "much preferring" the EFB and 7% "slightly preferring" the EFB in these situations.

Discussion

This study was conducted to determine the effect of utilizing charts and approach plates on the iPad®, as opposed to on paper, on pilot performance as measured by conformance to heading, course, altitude and airspeed requirements, time to set up an approach, and selection of appropriate approach minimums. The results of this study showed that there is a positive effect on pilot performance when using an EFB. The results for altitude, heading, airspeed, and localizer course were all statistically significant and showed an increase in performance when using the EFB.

When evaluating the time required to set up and brief an approach, the effect was again significant. When using the EFB, the average time to completion decreased by one minute and 29 seconds. This large decrease is extremely important in a situation where every second counts. One of the most compelling results from this study involved the participants choosing the wrong approach chart when using paper. As stated earlier, only 36% of the pilots were able to correctly identify the correct approach minimums on the first attempt when using paper. This was very surprising, but the number of ILS approaches in Memphis, and the various category minimums for a particular approach, evidently led to this confusion. When the pilots used the EFB, 100% of the participants chose the correct approach and the associated minimums on the first attempt. These are critical errors that, maybe more than the others, could result in an accident should the pilot attempt to use the wrong information for an approach. In this study, the EFB seemed to result in the elimination of these errors completely.

The second question this study sought to answer regarded the perceived workload and stress levels the pilots reported when using the two methods. The survey given at the end of the FTD session provided this data, and the results again all pointed toward the utility of the EFB. First, the participants were asked about their past experience using EFBs of any kind. The results of this question show that the majority (71%) of participants had never used an EFB before. When this result is considered along with the performance increases, it is clear that the iPad® provides a very user friendly design that requires little training or experience to master.

Questions two and three sought to determine how effective the participants felt both paper charts and the EFB were in this scenario. Of the pilots in this study 100% rated the EFB as "5-most effective" on the Likert scale provided. In comparison, the average effectiveness rating for the paper charts on the same scale was only 2.64. The survey responses also supported that the EFB was seen as easier to utilize during rapidly changing situations. All of the participants said that the EFB was "somewhat easier" or "much easier" to use than paper charts. Finally, the survey responses to determine the participant's preference of chart viewing method in the future during similar situations favored the EFB, with 93% of the participants “much preferring” the EFB. Not a single participant indicated that they preferred paper charts.

A majority of the literature that was reviewed prior to this study agrees with what was found. The study conducted by Chandra, Yeh, Riley, and Mangold (2003) stated that no matter how advanced EFBs become, they must stay uncomplicated and uncluttered, allowing them to remain easy to use. Many of these ergonomic and human factors issues are addressed by the iPad® with its focus on user interface and ease of use. The ForeFlight™ interface seems to be logical enough that the participants in this study were able to adapt quickly to it even though they had no previous experience and only a very brief tutorial before beginning the session.

Limitations

While this study showed a statistically significant increase in performance when using an EFB compared to paper charts, its findings do carry certain limitations. The population used in the study was one of convenience and does not represent a large cross-section of demographics when it comes to experience and age. Age, especially when dealing with technology such as this, can play a large role in how easy it is to transition to a new way of doing things in the cockpit. While the vast majority of participants had not used an iPad® specifically in a cockpit setting, the group consisted entirely of college students, who had undoubtedly used similar technology in other settings. The sample size was also quite low, which is a significant drawback to generalizability. This study also did not deal with the possibility of EFB equipment failure and how these pilots would deal with such a situation. There is a definite possibility that the pilots could become too dependent on technology and as a result lose their ability to maintain situational awareness. In addition, this study dealt with a single pilot scenario where one person must both set up and fly the aircraft simultaneously. Many operations require two pilots instead, and it may be that those operations would not see as large an increase in performance.

Future Research

More research needs to be conducted into the ability of the pilot population as a whole to adapt to this new technology. Research into performance gains involving two pilot environments, where one pilot can focus on setting up an approach while the other flies, should also be conducted. The question of what happens when a device fails in flight should be examined as well. Further study into the actual cost savings of using EFBs is also justified. If the entire in-flight library is completely transferred to a digital version, it may be cheaper for companies and individuals to maintain that library in the long run. Whatever the future brings to technology in aviation, there is no doubt that EFBs in some form will play a large part. With devices like the iPad® pilots can afford this technology in an easy to use package. The research conducted in this study determined that EFBs are likely to bring more safety and efficiency to the cockpit.

References

Alaska Airlines. (2011, May 27). *Alaska Airlines pilots go lean and green sith iPads.* Retrieved from http://splash.alaskasworld.com/Newsroom/ASNews/ASstories/

Allen, D. (2003). *EFB: Electronic flight bag.* Retrieved from http://www.boeing.com/commercial/aeromagazine/aero_23/EFB.pdf

Appcrawler. (2015). *Best Apps – Electronic Flight Bags.* Retrieved from http://appcrawlr.com/ios-apps/best-apps-electronic-flight-bag/

Chandra, D. C., Yeh, M., Riley, V., & Mangold, S. J. (2003). *Human factors considerations in the design and evaluation of electronic flight bags version 2.* John A. Volpe National Transportation Systems Center, U.S. Department of Transportation. Springfield, VA: National Technical Information Service.

Federal Aviation Administration [FAA]. (2003). AC No. 120-76A: Guidelines for the certification, airworthiness, and operational approval of electronic flight bag computing devices. Washington, D.C.

Flight Safety Foundation Editorial Staff. (2005). "Paperless cockpit" promises advances in safety, efficiency. *Flight Safety Digest* , pp. 1-10.

Fontaine, S. (2011). *Aircrews use tablets as "electronic flight bag"*. Retrieved from http://www.airforcetimes.com/news/2011/09/airforce-aircrews-use-tablets-as-electronic-flight-bag-092511/

ForeFlight LLC. (2011). *About us.* Retrieved from http://www.foreflight.com/about.php

Gibson, H. (2011, October 4). *The great approach plate debate*. Retrieved from http://pilotbrad.wordpress.com/2008/05/15/naco-or-jeppesen/

Hughes, D. (2009a, June 1). *EFB special section: airlines outline EFB benefits.* Retrieved from http://www.aviationtoday.com/av/issue/feature/EFB-Special-Section-Airlines-Outline-EFB-Benefits_32323.html

Hughes, D. (2009b, June 1). *EFB special section: Installing EFBs is no simple matter*. Retrieved from http://www.aviationtoday.com/av/issue/feature/EFB-Special-Section-Installing-EFBs-Is-No-Simple-Matter_32321.html

McKenna, Ed. (2012, July 1). Product focus: Electronic flight bags. *Avionics Today.* http://www.aviationtoday.com/av/issue/feature/Product-Focus-Electronic-Flight-Bags_76596.html#.VQLw1LfQeM8

Miller, J. (2011). *Foreflight blog home.* Retrieved from http://blog.foreflight.com/