Supporting Situational Awareness on Aviation Pilots: Key Insights Affecting the Use of Electronic Flight Bags Devices

Nuno Moura Lopes*, Manuela Aparicio, Fátima Trindade Neves
NOVA Information Management School (NOVA IMS), Universidade Nova de Lisboa, Portugal
* Corresponding author at: NOVA Information Management School - Universidade Nova de Lisboa, Campus de Campolide, 1070-312 Lisboa, Portugal
E-mail addresses: nuno.lopes@novaims.unl.pt (N.M. Lopes), manuela.aparicio@novaims.unl.pt (M. Aparicio), fneves@novaims.unl.pt (F.T. Neves)

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Nuno Moura Lopes*, Manuela Aparicio, Fátima Trindade Neves
NOVA Information Management School (NOVA IMS), Universidade Nova de Lisboa, Portugal
* Corresponding author at: NOVA Information Management School - Universidade Nova de Lisboa, Campus de Campolide, 1070-312 Lisboa, Portugal
E-mail addresses: nuno.lopes@novaims.unl.pt (N.M. Lopes), manuela.aparicio@novaims.unl.pt (M. Aparicio), fneves@novaims.unl.pt (F.T. Neves)

Abstract

Nowadays, aviation pilots often use tablets or mobile devices, to perform and help navigation flights. This becomes an issue when ab-initio pilots start to use Electronic Flight Bags (EFB) without any proper training during flight school. Some EFB are available to pilots on digital stores who can buy and install this software. Some available products are among others Foreflight, Garmin pilot and Skydemon often used for visual or instrument navigations. The use of these devices in aircrafts with analog instruments can divert the pilot attention from flying the aircraft, to being focused on changing settings with a head-down attitude, losing situational awareness from the remaining flight instruments. This article makes a review of the current body of literature in this area and analyses the accident data of one of the most important databases in accident investigation in aviation. Some findings point to the key insights affecting Situational Awareness and human-machine interaction on pilots using EFB.

Keywords: Electronic flight bags, General Aviation, Human Factors

Introduction

With the advance of technologies in aviation, manufactures are trying to build better aircraft instruments to automate as much as possible the flying tasks without compromising flying safety (Suppiah, Liu, Sang-A, Dattel, & Vincenzi, 2020). In older aircrafts, often used for hour building programs by recently graduated pilots, aviation checklists and aircraft manuals are usually old paper copies, indexed by a table of contents that contains all the procedures written in paragraphs, becoming difficult for the crew in a real-life emergency to search for the correct procedure or checklist to do in that specific situation (Crosland, Wang, Ray, Michelson, & Hutto, 2016). While flying the airplane, pilots are often consulting charts, navigating, communicating with air traffic control, and assessing weather conditions. Literature refers to the “head-down time” where the operator (driver, pilot or train diver) often divides the attention between the outside events and a head-down digital tool (Wilkins, 2018a). So manufacturers created an EFB, that allows pilots to carry numerous paper checklists, aircraft manuals, aeronautical charts, weather charts, performance and mass and balance in a single digital device (Suppiah et al., 2020). According to Xia, Lu, and He (2013, p. 1864) an EFB *“is an electronic display system used in the cockpit/cabin which can accommodate all the information carried by the crew, aeronautical charts, flight operation manuals, flight checklists, minimum equipment lists and flight log can be digitized to facilitate unit query gradually paperless cockpit”.* These charts are vital to guarantee flight safety and allow pilots to view all the information they need on a high-resolution screen (Suppiah et al., 2020). These EFB must be certified with a variety of tests that involves decompression, battery tests, user-friendly software, and hardware. Nevertheless, there are still human factors and hardware issues that undermine the proper utilization of these devices (Bhardwaj, Purdy, & Ieee, 2019). Bhardwaj et al. (2019) argue that for General Aviation (GA) pilots, there is little regulation on what devices are allowed to carry inside the cockpit as also the software applications used to perform a safe flight. Bhardwaj et al. (2019) also argue that today in the development of these EFB, security should be considered at design time and not retrofitting an old system such technique of assembly new EFB does not comply with Kocher (2004) security design recommendations. Nowadays EFB have been accepted by pilots as a means of decreasing cockpit workload and increase performance (Misra & Halleran, 2019). Some companies that are trying to evolve these EFB to another level, making them a primary tool for Instrument flight rules (IFR) flights, eliminating the communications between the pilot and the Air traffic Control, with regards to departure clearances and all other traffic information voice-based services (Diffenderfer et al., 2019). The technology is evolving at far most speed than the training of pilots on the use of these devices, with impact in pilots performance, skill degradation and loss of situational awareness (Misra & Halleran, 2019), and we aim to study further the support of EFB devices in pilot situational awareness. This paper is organized as follow: firstly, we describe the main concepts in GA and civil aviation about the use of EFB; secondly, we analyze the reports made from pilots in the ASRS database; Thirdly, we present how the empirical study was conducted and the results obtained followed by discussion and conclusions.

Theoretical background

The first made charts in paper support of airports were produced by Capt. Elrey B. Jeppesen in the 1930's. Being a Boeing Air transport pilot he noticed the lack of information that pilots had regarding obstacles, telegraph lines and data from the runways used at the time (Pschierer, Thompson, Ellerbrock, Haffner, & Ieee, 2012). From selling copies of his book to the first digital chart software almost 30 years passed, when JeppView was released in 1996 as two separate cd-roms for personal computers (Pschierer et al., 2012). The early versions were considered Airport Performance Laptop computers (ALPC) that equipped the flight deck of FedEx aircraft (Babb, 2017). There are three EFB configurations: Class 1 which is portable, Class 2 which is semiportable, and Class 3 which is installed avionics (Ates, 2017). The purpose of eliminating all the paper from the flight deck was achieved in 2002 where a class 3 integrated EFB was delivered in a Boeing 777 (Pschierer et al., 2012), which required airworthiness approval for Human and machine interface compatibility (Ates, 2017).

Table 1: Classification of existing EFB systems

Requirements	Class 1	Class 2	Class 3
Portable	√	√	
Do not require approval for airworthiness	√		
Are commercial Off the Shelf (COTS) - computer systems used for flight operations	√	√	
Connected to aircraft power with a certified power supply	√	√	
Are considered to controlled Portable Electronic devices	√	√	
Require the approval for airworthiness		√	√
Have no aircraft data connection except for certain conditions	√		
Are connected to the mounting device in the aircraft		√	
Require the approval of airworthiness		√	
Do not require the approval of airworthiness	√		
Installed Equipment			√
Certification on hardware, software, human machine interface			√
Can be connected to aircraft avionic system		√	

As the need for flying increases, due to tourism or the delivery of goods, it is crucial to habilitate aircrafts with safer systems for the crew to operate in a demanding environment, increasing safety procedures (Salas, 2010). So, it is essential to continue developing and improving technology not only for commercial airlines but also for General aviation aircrafts. One of the most common technologies adopted by pilots is the EFB (Suppiah et al., 2020). The EFB appeared as a digital tool device replacing the traditional paper flight bags carried by pilots regarding aeronautical charts, light operation manuals, flight checklists, weather information, minimum equipment lists and flight log (Ates, 2017). Traditional flight bags can weight up to 39.6 lb (18 Kg) where an EFB weighs 1.1 lb to 4.8 lb (0,5 kg to 2,2 kg), saving space in the cockpit and allowing pilots to manage tasks more quickly by retrieving information more efficiently (Chandrasekaran, Payan, Collins, & Mavris, 2020). This change also allows companies to digitalize processes and validations for Pilots tasks, enabling transparency of aircraft operational records (Haddock, 2015), improving flight safety and pilot performance (Suppiah et al., 2020). As technology advances, many tools used by pilots become highly automated, which helps reduce cockpit workload. However, a negative side effect is that Pilots may become dependent and complacent and suffer from skill degradation when these tools fail (Winter et al., 2018). One of the many features that EFB possesses is a fast Internet connection that provides updated real-time information about the aircraft, weather and reports to ground operations and aviation stockholders (Ates, 2017). Nevertheless, this process is not without faults. With any automation process or new technologies, EFB have raised several safety concerns (Suppiah et al., 2020). Some accidents were due to spatial deviation, runway incursion or an incorrect mass and balance calculation (Suppiah et al., 2020). German (2016) argues that if the Pilot is not aware that notifications are turned off, the EFB software fails to notify the pilot of an event. These phenomena was already studied by Endsley (1999), having pilots tend to be less responsible as they trust technology and are unaware of a malfunction in an automated system. In fact, the pilot can lose his situational awareness due to diverting attention from the other instruments of the aircraft (German, 2016). Salas (2010) also agrees that the human factor is essential with regards to the use of technology in terms of human performance and limitations. Training or recurrent practice is essential to deal with an automation failure during an emergency, preventing pilots skills degradation when dealing with entire automation systems (Casner, Geven, Recker, & Schooler, 2014; Winter et al., 2018). Table 2 resumes the principal studies on EFB.

Table 2: Recent studies on EFB.

Author	Journal	Study purpose	Method/Model
(Diffenderfer, Baumgartner, Long, Pertsch, & Iacobucci, 2020)	AIAA/IEEE 39th Digital Avionics Systems Conference (DASC) (pp. 1-8). IEEE	Mobile IFR services	Prototype development
(Bhardwaj et al., 2019)	In 2019 IEEE National Aerospace and	Mitigate human factors and hardware related concerns	Prototype development

Author	Journal	Study purpose	Method/Model
	Electronics Conference (NAECON) (pp. 181-184). IEEE		
(Wilkins, 2018b)	Transportation research record, 2672(23), 137-145.	Improve cognitive assistance for pilots by analyzing head down time during approaches to land	Study to analyze new ways of minimizing head down time by Pilots
(Winter et al., 2018)	Safety science, 103, 280-286.	Comparison between Pilots using paper navigation charts and electronic charts	Lab experiment with 29 Pilots, tested on the use of traditional flight bags versus EFB
(Suppiah et al., 2020)	International Journal of Aviation, Aeronautics, and Aerospace, 7(4), 4.	Analyze Pilots performance with the use of an EFB	SPSS study sample with 16 Private pilots tested on the use of EFB with focus on Pilot performance
(Hendrarini & Ema, 2020)	Journal of Physics: Conference Series (Vol. 1516, No. 1, p. 012053). IOP Publishing.	Virtual aircraft instruments to improve learning techniques on how to deal with real flight situations	Monte Carlo method for verification and validation
(Diffenderfer et al., 2019)	In 2019 IEEE/AIAA 38th Digital Avionics Systems Conference (DASC) (pp. 1-8). IEEE.	Use of mobile devices by Pilots to obtain departure clearances	Prototype development
(Fala & Marais, 2019)	In AIAA Aviation 2019 Forum (p. 3443).	Risk assessment and potential biases for general aviation Pilots	On-line Survey
(Misra & Halleran, 2019)	Collegiate Aviation Review International, 37(2).	Automation and EFBs in Flight planning	Mixed factorial design with within subjects survey and between-subjects experimental components
(Martinussen & Hunter, 2017)	Aviation psychology and human	Physiological effects on pilot performance	Overview of the role psychology plays in aviation, system design,

Author	Journal	Study purpose	Method/Model
	factors. CRC Press.		selection and training of pilots, characteristics of pilots, safety, and passenger behavior
(Chandrasekaran et al., 2020)	Aerospace Science and Technology, 98, 105665.	The use of EFB technology to prevent accidents. Comparison between several EFB's available on the market	Review of some commercial EFBs with focus on the main safety functionalities

From table 2 we see that many of the most recent studies focus on the human-machine problem on the use of EFB. Human factors are associated with lack of performance, flying skills degradation, and loss of situational awareness by pilots. There are also flight safety concerns in the event of an EFB failure due to the strong dependency by pilots on the existing cockpit automation.

Methodology and analysis

The source for this study is the Aviation Safety Reporting System (ARSR), a database administered by the National Aeronautics and Space Administration (NASA). The search criteria used were all the Incidents between January 1995 and September 2021 with Federal aviation regs Part 121, Part 135, and Part 91, where the report text contains, amongst other, terms such as EFB, electronic flight bag, performance computer, onboard performance compute, tablet pc, tablet, paperless, electronic chart, auxiliary performance computer, laptop. From the query 1869 records were identified, related to EFB and Tablet reports. The dataset was refined and reduced to 299 reports (Figure 1), where 166 were related to EFB, two related to Portable device computers (PDC), 112 related to Tablets, and 19 related to Laptop computers.

Figure 1: Number of reported in the ARSR database related to EFB, Tablets and PFD per year

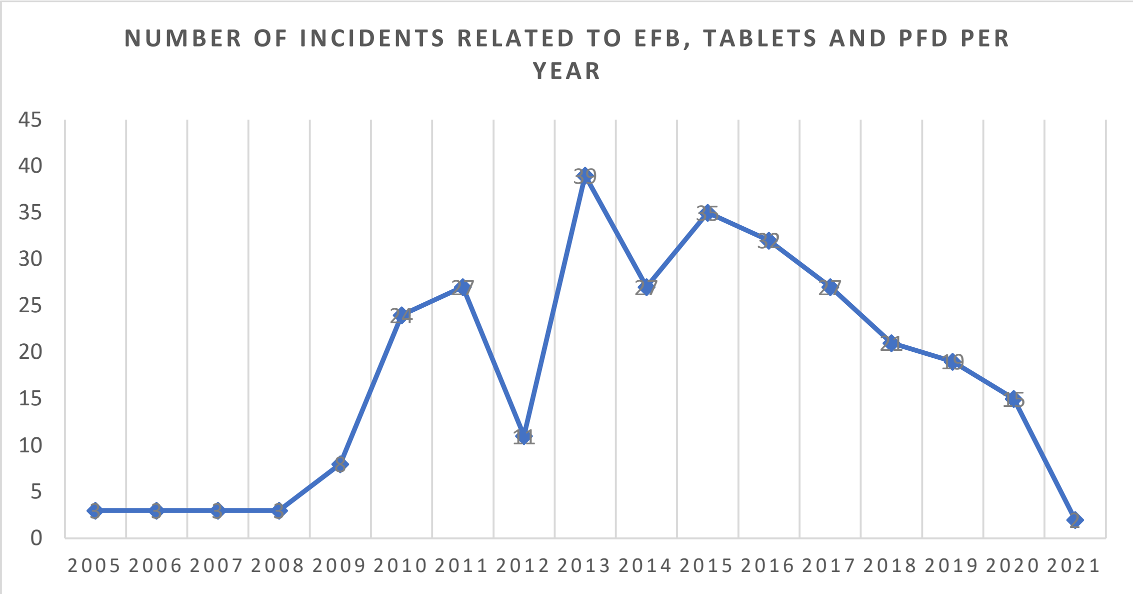

Table 3 shows the number of reports under the FAR presented in the ARSR database. Part 91 is considered by the Federal Aviation Administration (FAA) as GA operations which comprise all private flights, part 121 are scheduled air carriers, and part 135 comprises all charter private aviation jets and helicopters.

Table 3: Number of reports under Federal Aviation Regulations (FAR)

Federal Aviation Regs	Description	Number of reports
Part 91	General Operating and Flight Rules;	567
Part 121	Operating Requirements: Domestic, Flag, and Supplemental Operations;	1241
Part 135	Operating Requirements: Commuter and On Demand Operations and Rules Governing Persons on Board Such Aircraft;	59

Figure 2 contains a graph visually presenting the correlation from incident reports. It was created using Circos (Krzywinski et al., 2009) to show the relations between the primary information devices used in aviation, and the effect of a failure or malfunction of either a EFB, a Tablet, a Laptop or a PFD. The relations are made by colored ribbons, quantitatively by the thickness of the scale shown.

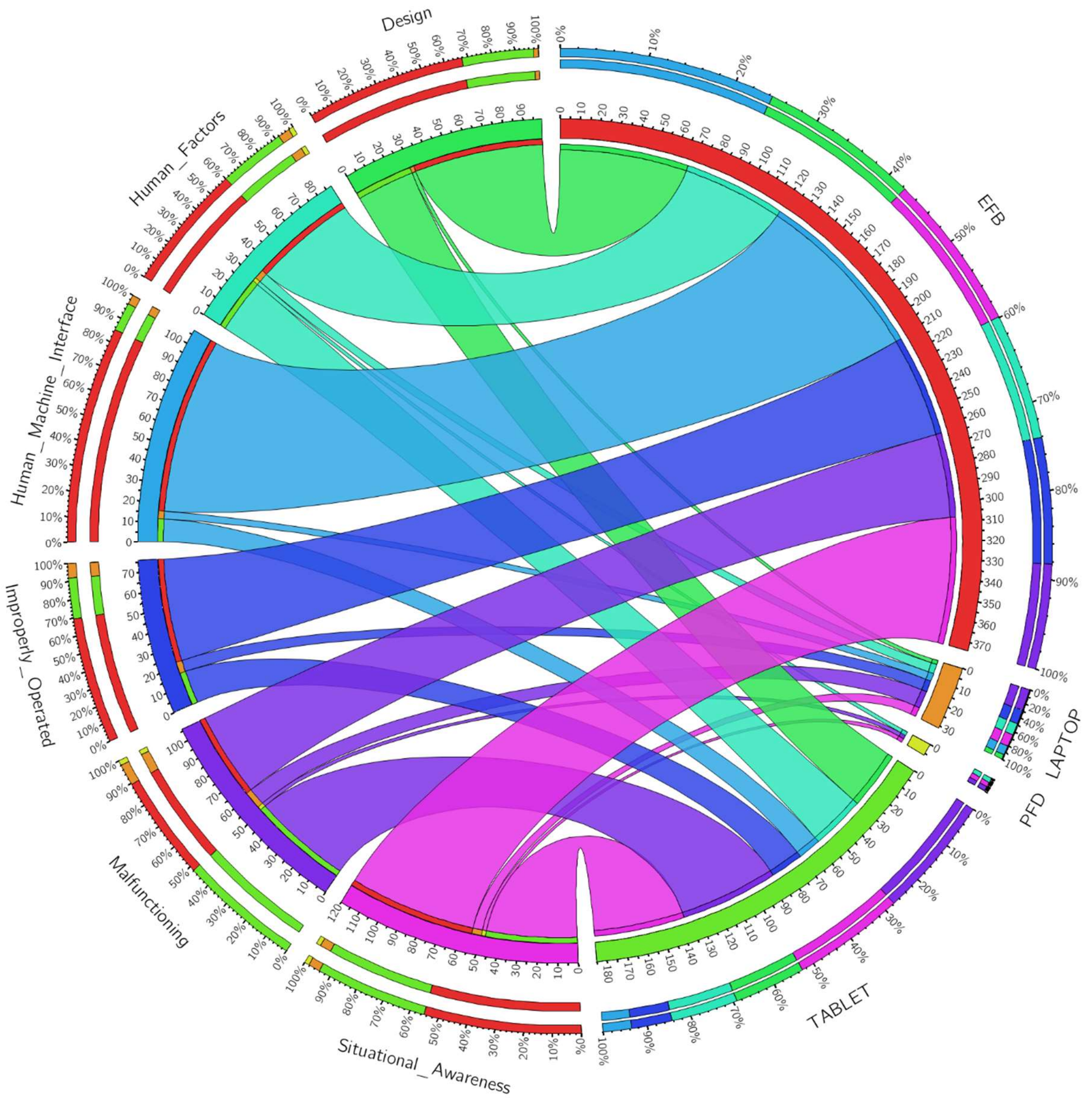

Figure 2: Relation from Incident reports

From the graph analysis, we can see that EFB are the ones with the most significant number of reports, followed by Tablet devices, being Laptop and PFD almost residual. There is a strong relation between EFB and Tablet types of devices and the loss of situational awareness by the crews. Also, from the figure EFB, when malfunctioning is responsible for 40% of the incident reports, and Situational Awareness and the Human-machine Interface are the most ranked categories on incidents. Other categories are similar in the impact number of occurrences.

Conclusions

In this study, we approached Situational Awareness on aviation pilots from the point of view of the frequency and type of incidents from the ARSR database, relating the impacts on the use of EFB and other devices used by pilots to monitor flight conditions. Also, we presented from the body of literature the most important and updated studies providing key insights affecting the use of EFB devices. Finally, the human factors, namely the Human-machine interaction, are also emerged as a determinant factor in the use of EFB, also impacting on pilots' situational awareness.

Limitations and future work

The data for this paper were collected in one database, the Aviation Safety Reporting System (ASRS). We accept that the use of another accident database data could contribute to a better understanding of the topic presented. Such approach could contribute to reduce eventual subjective bias, typical of database queries. Further study on the use of EFB's and their design should be deepened to better understand the human-interaction factor with regards to a more user-friendly software.

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