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EFFECTS OF AUTOMATION AND ELECTRONIC DEVICES ON BOARD AIRCRAFT ON PILOT SKILLS, TRAINING REQUIREMENTS AND FLIGHT SAFETY

Summary
The present and future challenges of commercial air transport industry require maintaining growth trends in air traffic and at the same time easing congestion in the skies without compromising high safety standards. This all leads to natural evolution of the aircraft cockpit environment. The progress starts now with implementation of head-up displays, airport moving maps, interactive electronic checklists, enhanced vision using infrared cameras to enable night time vision and synthetic 3-D vision systems. In the future, technology development will continue with I4D operations, digital taxi real-time uplink of the cleared taxi route via Controller-Pilot Data Link Communication and much more. These modern cockpit features and their necessary future upgrades enable pilots to capitalize on their strengths and help them manage their weaknesses.

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Information from these systems are presented to the pilots in transparent manner which makes their decision-making process more efficient and safer, especially under stress. Taking into consideration future trends in the cockpit environment, the growth of the air transport and safety requirements, it is necessary to review the role of pilots. Aviation is a sphere where progress and continuous innovation is inevitable. Therefore, it is necessary to keep up with the evolution and adapt also the pilot training and education. Many major world top rated airlines have already implemented for example evidence-based trainings as they realized that the role of the pilot in the cockpit is changing. The basic pilot skills are essential but in today's air transport operation we also need to take into account that pilots need to have certain managerial skills and therefore balance the training accordingly to make it more efficient. Whether we like it or not, the times of visual approaches and manual flying, especially in big commercial operations, are slowly disappearing. We need to understand this progress and adjust the structure of the pilot training accordingly to be able to deliver the best level of safety efficiency. The paper also deals with the use of portable multimedia devices for VFR flights. It explains the basic terms concerning the use of portable electronic devices on-board aircraft. It analyses the relevant international and national legislation for the use of portable electronic devices on-board aircraft. It includes a survey of the available devices, accessories and software on the market. An analysis and comparison of the devices, based on their technical specifications is included as well. The paper also deals with various aspects of the use of portable multimedia devices for a flight school. It reviews the whole process of selecting a suitable operating system, device, accessories and software with an example of calculation of the required financial expenses. A comparison of the devices based on the battery life in relation to the selected aircraft is also included. Furthermore, the paper considers the mounting options of the devices in the cockpit, points out to required changes in the operational procedures within the flight school and highlights the potential assets which application of portable electronic devices brings.

Key words*: automation, future aircraft cockpit environment, human-machine interface, safety challenges, situational awareness, skills degradation, training, EFB, electronic flight bag, tablet, VFR, AMC 20-25, application, iOS, Android*

Introduction

Since the very first flight on December 17, 1903 when one of the Wright brothers successfully flew for the first time in the history and his ground speed reached 6.8 mph, the aviation has made enormous progress.[1] If we want to analyze the evolution, we need to settle a baseline. For purposes of this paper, we conducted analyses of automation in the aircraft cockpit environment. More specifically, how the pilots perceive it and what is their attitude towards the cockpit

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[1] Crouch T., *Who Flew First?*, Air & Space Magazine, September 2013.

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automation. Based on this analysis, we can better understand how to adjust training to make aviation more efficient and safe. The main goal in the adoption of aircraft cockpit automation technologies is to decrease the errors caused by human factors. On the other hand, real operation and empirical research showed that the automation causes new types of errors in the cockpit. Based on aviation accidents survey, the automation errors are mostly related to FMS (Flight Management System) and sudden loss of automation. The FMS supports pilots in flight planning, navigation, performance management and monitoring of flight. The automation enables pilots to capitalize on their strengths and should help them manage their weaknesses. In order to have a better understanding of this thought, it is necessary to know pilots' attitude towards this phenomena. To understand it, we conducted a survey which was aimed at the effect of high automation in the aircraft cockpit environment and its impact on flight safety. The survey was conducted on a group of 128 air transport pilots of the most advanced airline jet aircraft (B787, B777, B737NG, A320, A330 and A380). The group consisted of airline instructors/examiners, line captains, senior first officers, first officers and second officers. The pilots were from major world airlines such as Qatar Airways, Amiri, Etihad, Emirates, Norwegian, Vietnam Airways, Ryanair, Travel Service and Lufthansa. Average age of the respondents was 38. 10% of the pilots were women and 90% men. Average flown hours of the pilots were 9500 (total flight time). The summary of personal interviews and the survey is shown in the tables and charts hereinafter. For global understanding of the high cockpit automation, its evolution, challenges, future training requirements and its impact on overall safety, it is necessary to compare current perception of the automation from all points of view – pilots, companies, training, ATC, industry and future air transport growth. The survey conducted for the purposes of this paper took into account the point of view of pilots.

1. Skills degradation, situational, awareness, advantages, safety challenges

Looking back to history, big wars produced many military pilots and set a baseline for the big boom of aviation in terms of technology and personnel. The source of pilots was huge and pilot flying skills were, thanks to thousands of flown hours without autopilot, amazing. Later, between 1970s and 1990s, civil pilots earned their honourable place in

aviation maintaining perfect understanding of the aircraft logic. It was standard that pilots grew up in aero clubs closely connected with all the aspects of aviation surrounded by other passionate and dedicated pilots and ground staff. Later development of aviation technology brought innovations and need for crew resource management (CRM) among the crew members. This again enhanced the professionalism and safety level of air transport. Looking at global aviation industry now, it is obvious that the air traffic has reached its capacity ceiling at many airports and airspaces. On top of that, air traffic is still growing. Even the world fleets' growth rate is tremendous and the number of new aircraft being delivered every year continuously increases[2]. This production and deliveries will in turn drive a growing need in well-trained pilots and crews to fly and operate these aircraft. Human resources are a limiting factor. Older generation is retiring and more and more new pilots need to be trained to proficiency. The training needs to be completed as fast and as cheap as possible in order to be competitive and efficient. We need to cover the world big need for air personnel. One of the answers is automation. Cockpit automation brings great advantages. Year 2015 prided itself for fatal accidents translating into a rate of 0,03 accidents per million flights[3]. If look at world aircraft fleets, it is obvious that highly automated aircraft types have significantly lower fatal rate over years.[4] The fact is, the automation also brings new challenges. For experienced pilots who have built sufficient pilot skills, it is very good and strong tool. On the other hand, for pilots, especially cadets/second officers, who were not given enough time to absorb basic flying skills and experience, it could bring challenges such as insufficient understanding of some principles, logic of the systems and more. The recent aviation fatal accidents confirm this.[5] Generally, pilots with experience have strong intuitive reactions (basic pilot skills). If cadet pilots are not given enough practise and opportunity to build these intuitive reactions and depend solely on automation, this is not the right way how the cockpit automation should be used. It is caused by the pressure from the aviation industry on producing pilots fast. Airlines are aware of this development

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[2] Airbus, A Statistical Analysis of Commercial Aviation Accidents 1958-2015.
[3] Airbus, A Statistical Analysis of Commercial Aviation Accidents 1958-2015.
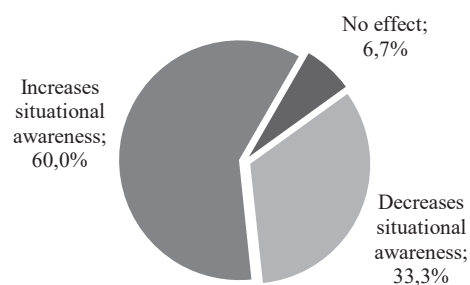[4] Boeing, Statistical Summary of Commercial Jet Airplane Accidents Worldwide Operations 1959–2015.
[5] Ibid.

and of the high reliability of the aircraft systems and encourage pilots to use automation up to its full capacity. They know how to prioritise and optimise the training to meet the current needs. A good idea how to maintain and enhance pilots' flying skills is to give them for example 1 extra simulator per year to practice manual flying (no autopilot, no autothrust, no flight director, manual go-arounds, visual circuits and more). Such a solution of course brings high costs and is demanding on simulator capacity. Another way how to increase the awareness is to encourage pilots to keep up with the automation, its logic and function and educate them to fully understand it. The results of the survey and interviews indicate that pilots have quite good awareness of all the automation. We need to keep up and lay emphasis especially on second officers/cadets as the current fast trainings and booming air transport development do not provide them with sufficient time to adapt.
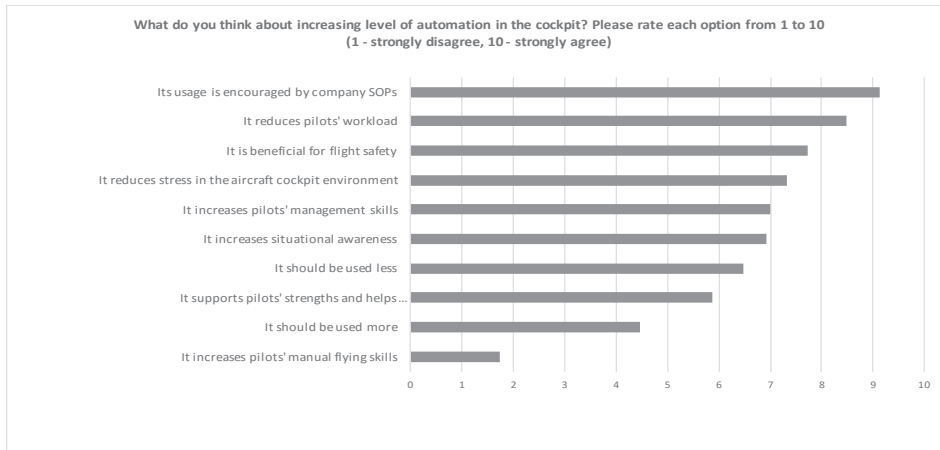
2. Results of the survey

The following charts indicate various pilots' attitudes as regards the progressive deployment of the automation to the cockpit environment.

Figure 1. How does high level of automation in the aircraft cockpit effect situational awareness of pilots?

Based on Figure 1, 60% of the survey respondents agreed that high level of cockpit automation increases situational awareness. This confirms the main objective of the automation – to increase pilots' situational awareness by decreasing their workload.

Figure 2 .What do you think about increasing level of automation in the cockpit? Please rate each option from 1 to 10 (1 - strongly disagree, 10 - strongly agree).

Regarding Figure 2, pilots generally strongly agreed that the usage of the cockpit automation is encouraged by the company's standard operating procedures, it reduces their workload, and it is beneficial for flight safety and increases pilots' management skills and situational awareness. The lower weighted average of the results showed that pilots agreed the automation should be used less and at the same time it helps to manage their weaknesses and supports their strengths. Pilots generally disagreed that the automation should be used more and strongly disagreed that the automation increases pilots' manual flying skills.

Figure 3. High level of automation in the aircraft cockpit environment brings more advantages or disadvantages for flight operations and safety?
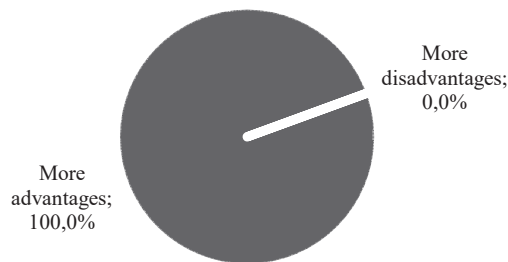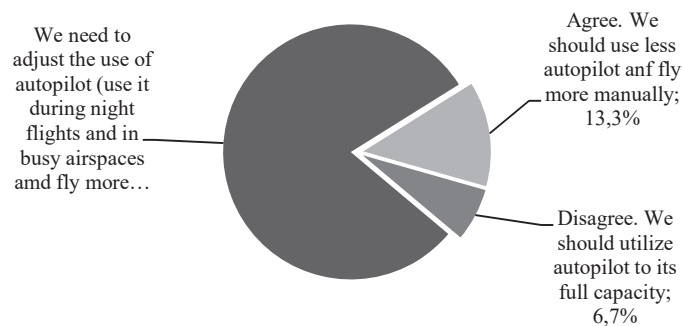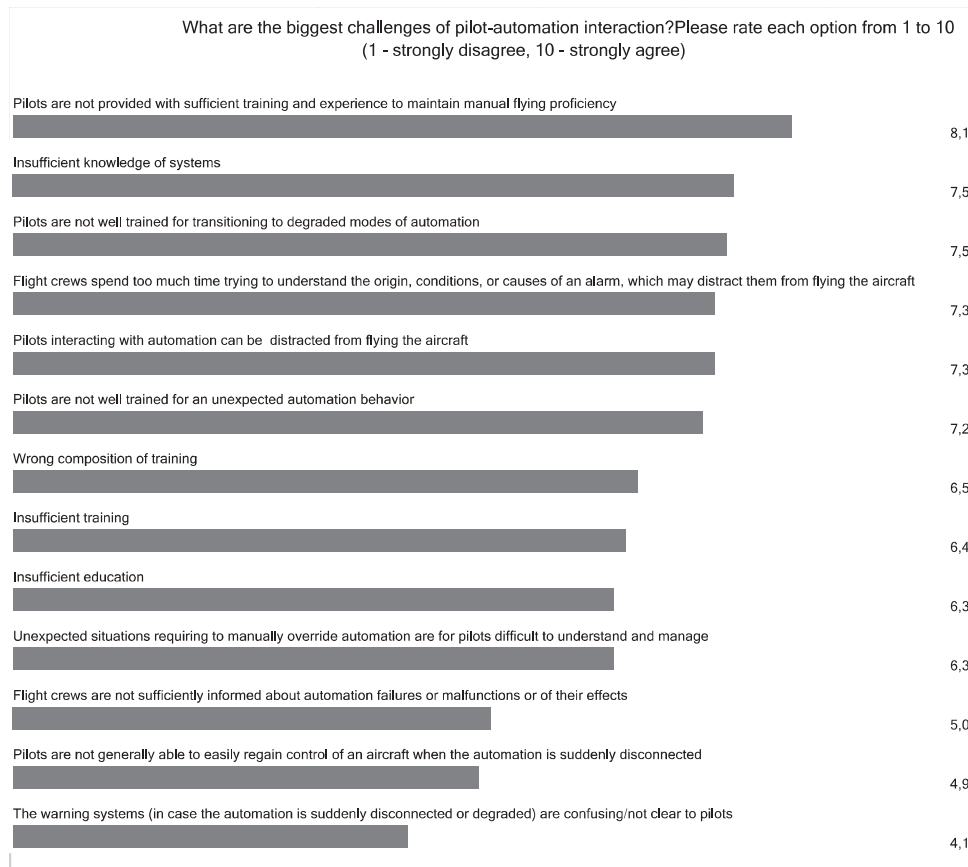
Figure 3 brings surprisingly united opinion on advantages /disadvantages which brings high level of cockpit automation regarding flight operations and safety. 100% of respondents agreed it brings more advantages than disadvantages. This result definitely confirms the purpose of the cockpit automation.

Figure 4. During routine line operations, we should encourage more manual flying and postpone engagement/disengagement of the autopilot.
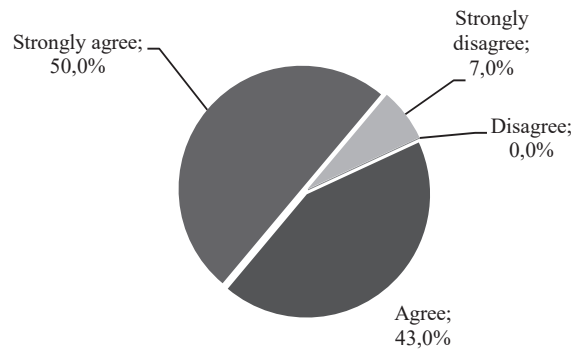

The respondents' opinions slightly differed in question regarding encouraging more manual flying and postponing engagement/disengagement of the autopilot during routine line operations (see Figure 4). 80% of the pilots agreed we need to adjust the use of autopilot (use it during night flights and in busy airspaces and fly more manually in more relaxed airspaces). 13,3% of the pilots agreed we should use less autopilot and fly more manually and 6,7% agreed that we should utilise the autopilot to its full capacity.

Figure 5. What are the biggest challenges of pilot- automation interaction? Please rate each option from 1 to 10 (1 - strongly disagree, 10 - strongly agree).

What are the biggest challenges of pilot-automation interaction?Please rate each option from 1 to 10
(1 - strongly disagree, 10 - strongly agree)

Pilots are not provided with sufficient training and experience to maintain manual flying proficiency
8,1

Insufficient knowledge of systems
7,5

Pilots are not well trained for transitioning to degraded modes of automation
7,5

Flight crews spend too much time trying to understand the origin, conditions, or causes of an alarm, which may distract them from flying the aircraft
7,3

Pilots interacting with automation can be distracted from flying the aircraft
7,3

Pilots are not well trained for an unexpected automation behavior
7,2

Wrong composition of training
6,5

Insufficient training
6,4

Insufficient education
6,3

Unexpected situations requiring to manually override automation are for pilots difficult to understand and manage
6,3

Flight crews are not sufficiently informed about automation failures or malfunctions or of their effects
5,0

Pilots are not generally able to easily regain control of an aircraft when the automation is suddenly disconnected
4,9

The warning systems (in case the automation is suddenly disconnected or degraded) are confusing/not clear to pilots
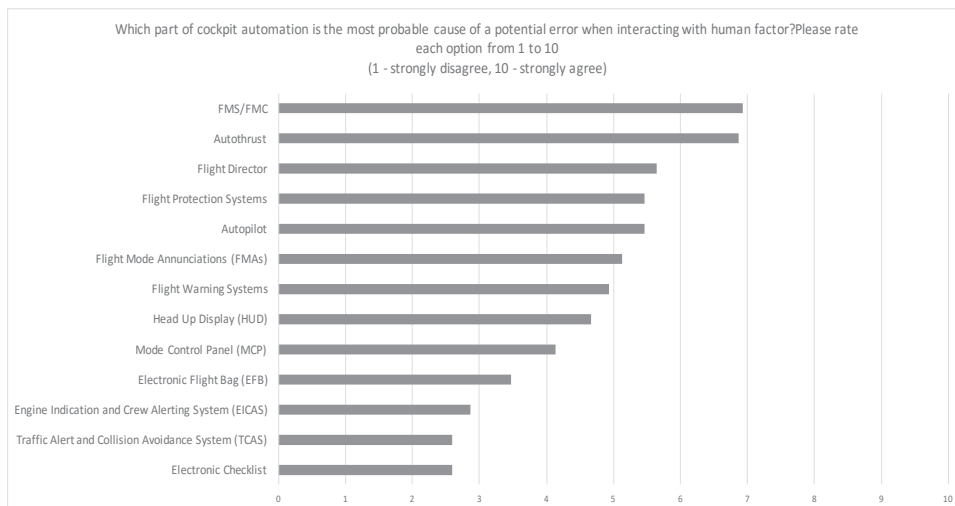4,1

Based on the pilots' responses, the biggest challenge of pilot-automation interaction (see Figure 5) is that pilots are not provided with sufficient training and experience to maintain manual flying proficiency. Here we can ask questions: What kind of proficiency is more important nowadays and what kind of proficiency will be of higher importance in the future: the right usage of the automation or excellent manual flying skills? How to balance these two closely connected requirements efficiently? Next, pilots agreed that insufficient knowledge of the systems is also a drawback. The respondents assigned high priority to difficulties in transitioning from automated to manual flight. This is obviously caused by insufficient manual flying skills. This is why pilots do not feel comfortable and confident enough during manual flying any more.

Figure 6. Basic manual and cognitive flying skills tend to decline because of lack of practice and feel for the aircraft can deteriorate?

Based on the chart shown in Figure 6,93% of the pilots agreed that basic manual and cognitive flying skills tend to decline because of lack of practice and feel for the aircraft can deteriorate. 7% strongly disagreed.
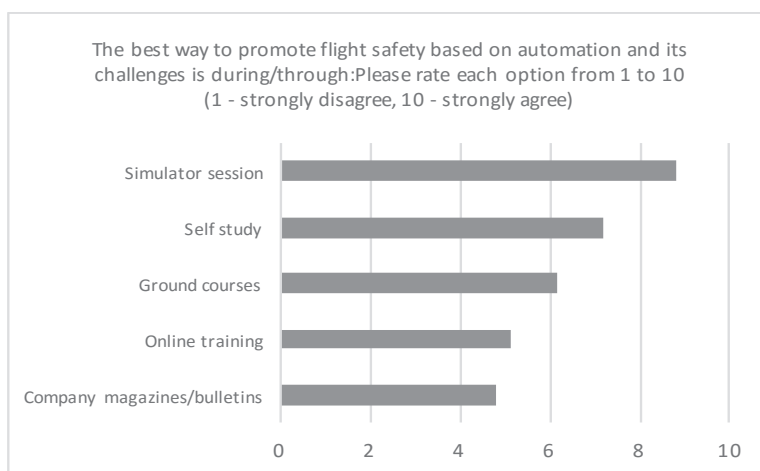
Figure 7. Which part of cockpit automation is the most probable cause of a potential error when interacting with human factor? Please rate each option from 1 to 10 (1 - strongly disagree, 10 - strongly agree) .

Some parts of cockpit automation are more probable cause of a potential error when interacting with human factor. Figure 7 depicts the pilots' opinions on the importance of these automation systems. The highest rating had FMS/FMC, then autothrust, flight director, flight
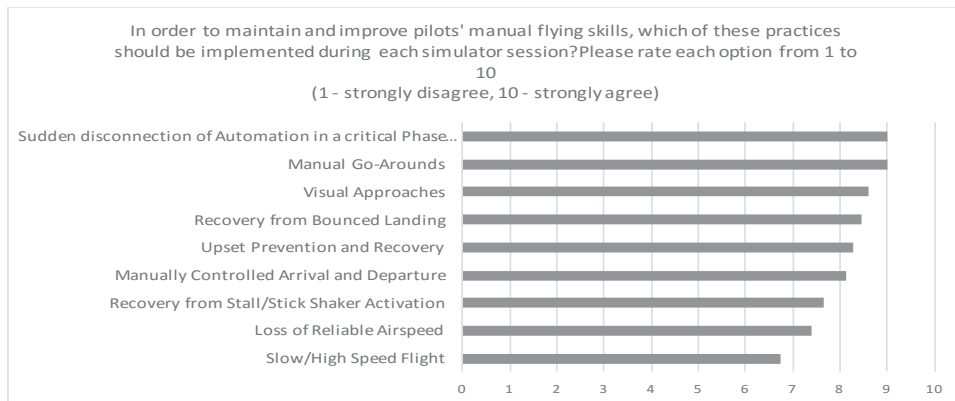
protection systems, autopilot and flight mode annunciation (FMA). The rest of the selected systems were assigned low importance. These systems were: flight warning systems, head up display (HUD) and mode control panel (MCP). Pilots disagreed that electronic flight bag (EFB), engine indication and crew alerting system (EICAS), traffic alert and collision avoidance system (TCAS) and electronic checklists would have significant impact on the potential error when interacting with the human factor.

Figure 8. The best way to promote flight safety based on automation and its challenges is during/through: Please rate each option from 1 to 10 (1 - strongly disagree, 10 - strongly agree).

In the survey, the pilots generally agreed that the best way to promote flight safety based on automation and its challenges is through simulator sessions, self-study and ground courses (Figure 8).

Figure 9. In order to maintain and improve pilots' manual flying skills, which of these practices should be implemented during each simulator session? Please rate each option from 1 to 10 (1 - strongly disagree, 10 - strongly agree).

In order to maintain and improve pilots' manual flying skills, the respondents were asked which practices should be implemented during each simulator session. The highest priority was given to sudden disconnection of autopilot in a critical phase of flight, manual go-arounds, visual approaches, recovery from bounced landings, upset prevention and recovery, manually controlled arrivals and departures, recovery from stall/stick shaker and loss of reliable airspeed. Little lower importance was given to slow/high speed flight practise (Figure 9). Based on these results, pilot generally want more manual flight training during the simulator sessions.

Figure 10. Is Evidence Based Training (EBT) suitable for highly automated cockpit environment?
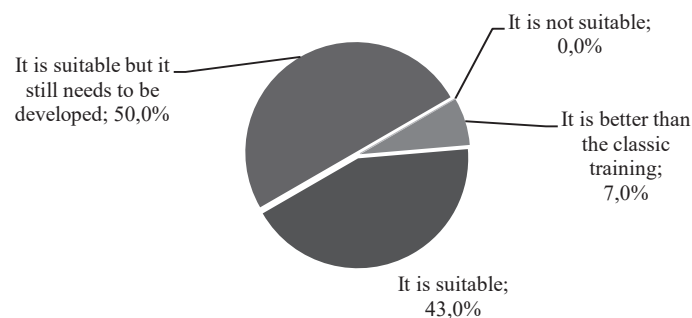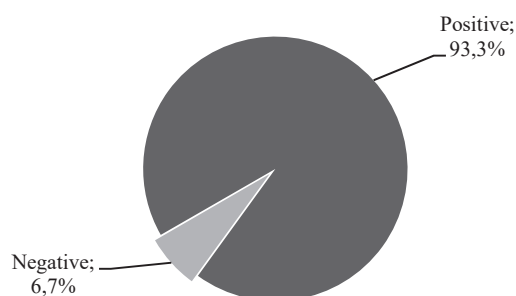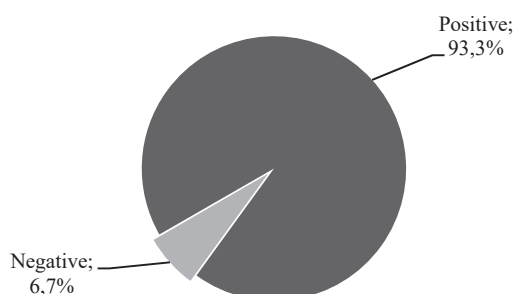

Figure 10 shows that the pilots' feedback on the evidence based training (EBT) is generally good.

Figure 11. What is the effect of high automation in cockpit on Examiners/ Instructor?
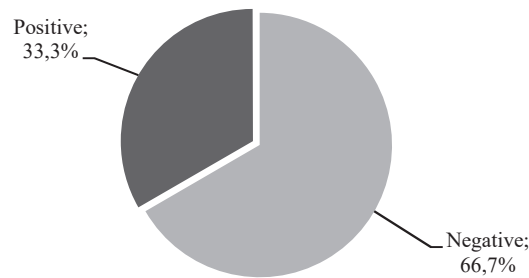

Regarding the effect of high automation in cockpit on Examiners/Instructor, majority of the respondents agreed the effect is positive. It lowers their workload and they can focus more on training. This makes the training process more efficient. See Figure 11.

Figure 12. What is the effect of high automation in cockpit on line Captains/First Officers?
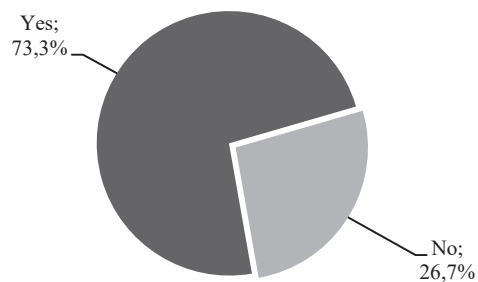

Regarding the effect of high automation in cockpit on line Captains/First Officers, it is also generally agreed that the effect is positive. Provided that the professional captains and first officers have sufficient skills, the automation makes the operations way more efficient and safe. See Figure 12.

Figure 13. What is the effect of high automation in cockpit on Second Officers/Cadets?
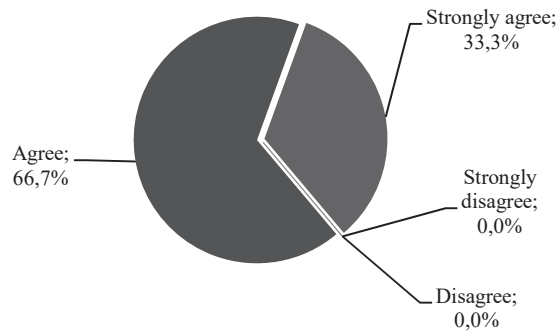
Approximately 67% of the respondents agreed that the effect of high automation in cockpit on Second Officers/Cadets is negative. The second officers/cadets need to build "intuitive" flying skills and get as much manual flying experience as possible before relying on automation. In this way they fully understand the logic behind the automation and use the automation right. See Figure 13.

Figure 14. Do current training methods provide sufficient confidence for pilots using more advanced and fully automated systems in the aircraft cockpit?
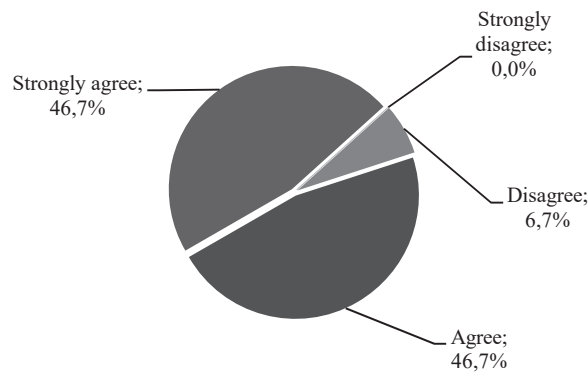

The chart in Figure 14 shows that approximately 73% of the respondents agreed that the current training methods provide sufficient confidence for pilots using more advanced and fully automated systems in the aircraft cockpit.

Figure 15. High level of automation in the aircraft cockpit environment increases flight operations efficiency and flight safety.

Based on Figure 15, approximately 67% of the pilots agreed that high level of automation in the aircraft cockpit environment increases flight operations efficiency and flight safety.

Figure 16. Visual approaches should be practiced during routine line operation when conditions permit.

Approximately 93% of the respondents agreed that visual approaches should be practiced during routine line operation when conditions permit. See Figure 16. This result confirms the need for more manual flying practice.

Figure 17. Evaluate how the training (you have completed) prepared you for the high level of automation in the aircraft cockpit.

Finally, Figure 17 depicts various opinions on how the training (the pilots have completed) prepared them for the high level of automation in the aircraft cockpit. 6,7% of the respondents thought the preparation was poor. 20% thought it was excellent, 26,7% considered it to be sufficient and 46,7% found it to be good.

3. Discussions and interview results

Some additional ideas were collected on what should be changed in current pilot training (FTO or airline level) so it better addresses issues of increased level of automation in the aircraft cockpit. Many of the respondents agreed on high need for more manual flying in order to maintain skills. Next, there is need for more normal manoeuvre training without the head up display (HUD) and autothrust as many major airlines do not allow it under normal operations. Results also showed the pilots' need for more upset recovery simulator training and an advanced knowledge of automatic modes logic. Some of the respondents would like to be given an opportunity to provide their companies with specific feedback about their specific training needs. Generally, both examiners/instructors and line pilots were happy with the new trend of training – evidence based training (EBT). They found it efficient. Few respondents expressed their concern on the general ability of pilots regarding the usage of various levels or parts of automation that indicates a widespread lack of in-depth knowledge of how the system should be used efficiently; indicating further basic training should be applied to advance system knowledge before continuing to use the automation in

normal or non-normal situations. Especially airlines examiners/instructors agreed that there is need for more flying experience without using autopilot before joining an airline and better understanding of autopilot modes.

4. Electronic devices on board aircraft

Technological progress of mankind is unstoppable and it penetrates all types of industries. Air transport is no exception. Throughout its history it has recorded several breakthrough milestones. Apart from the advancement in the areas of aircraft engines and airframes, lately we were witnesses to significant changes in the field of avionic equipment of aircraft. While classic analogue dials were once an essential part of any cockpit, nowadays they are more likely a relic and their function is being taken over by multifunctional displays (glass cockpit) that we can find in many general aviation airplanes. Similar fate also awaits paper documentation necessary for flight. Nowadays it can be substituted by electronic devices with a characteristic name Electronic Flight Bag (EFB) without any problems. The goal of this paper was to summarize and analyse the issue of portable electronic devices usage aboard the aircraft with an emphasis on utilization for VFR (Visual Flight Rules) flights.

Figure 17. Tablet usage during a flight.

Source: http://www.aviatorshop.eu/en/kneeboards/211-kneeboard-i-pilot-for-regular-ipad.html (May 10, 2014).

5. Electronic flight bag

The beginnings of the EFB stretch back to the year 1991 when the FedEx Company as a first started to utilize ordinary laptop computers to compute operational parameters directly on-board the aircraft. In year 1996 a German company Aero Lloyd introduced a system called Flight Management Desktop (FMD). It consisted of two laptops that enabled the calculation of operational parameters and they dispose of the database of aeronautical charts. After agreement with a German Aviation Authority has Aero Lloyd Company, as a first in the world, certified a so called paperless cockpit – a cockpit with no paper communication. The evolution of EFB has advanced very rapidly and more and more companies were equipping their aircraft with it. Nowadays this system is widely recognized and used in the air transport.[6] Usage of EFB was at the beginning narrowly oriented to the commercial air transport. It took more than 20 years of IT technologies development to get such devices aboard the aircraft of general aviation. The situation has changed rapidly in 2010 when first tablets were introduced. They have become very accessible in a very short time and they found application in general aviation.

6. Division of devices by hardware

6.1 Portable EFB

Portable EFB is defined as a device that provides a host platform for software equipment. It is used in the aircraft cockpit but is not a part of certified equipment of the aircraft.

Additional characteristics:

- device can be used aboard the aircraft as well as away from it,
- device is a host platform for software application types A and B as well as additional applications (that are not a part of EFB),
- device is a Portable Electronic Device (PED). PED is characterized as any electronic device usually (but not always) appertaining to the category of consumer electronics brought aboard the aircraft by crew

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[6] Hengi, B.I., *Airlines Worldwide*. Midland Publishing 2000.
Kratochvil, P., *EFB - Electronic Flight Bag*, In flyMag [online] 2013 [cit. 2014-5-3] http://www.flymag.cz/article.php?id=9208 (date of access: May 10, 2014).

members, passengers or as a part of the cargo load and it is not included in the list of aircraft's certified equipment. This category includes all devices that consume electric energy. This energy can be supplied either by an built-in battery (rechargeable or not) or the device can be plugged-in to a specialized socket,

- weight, dimensions, shape and placement of the EFB must not compromise the flight safety,

- device can be supplied from the aircraft network through certified socket,

- in case the device is mounted in a holder easy and tool-free removal by crew must be possible. Securing device in the holder does not present an action of maintenance,

- device can be a part of the system that includes built-in EFB sources that are part of aircraft's certified equipment,

- built-in components of EFB system are part of aircraft's certified equipment with an intention of mounting of the portable EFB into the mount and/or connection to other systems.

If the device belongs to T-PED (with intentional broadcasting) category the terms for broadcast use are listed in the approved Aircraft Flight Manual (AFM). In case these are not included in the AFM the broadcast is only permitted during non-critical phases of flight, device can be used in all flight phases if it is mounted in the certified mount or is places differently in a way that ensures its normal usability. Devices that don't meet the above mentioned characteristics have to be safely stored (not used) during the critical phases of the flight.

Portable EFB devices belong to group of controlled PEDs. This means that they are a subject of administrative check of the user. This includes, inter alia, the allocation check to specified aircraft or personnel and making sure that no unauthorised changes to hardware, software or databases were carried out. Every EFB component that is inaccessible by crew in the cockpit or is non-removable has to be installed within the framework of aircraft's certified equipment with a corresponding Type

Certificate (TC), changed Type Certificate (changed TC) or supplement Type Certificate (S)TC).[7]

6.2. Built-in EFB

Built-in EFB is defined as a device that provides a host platform for software equipment, it is installed in the aircraft and it is a part of aircraft's certified equipment which is a subject of Certificate of Airworthiness.[8]

Additional characteristics:

- device is operated on the grounds of aircraft type configuration,
- device can be apart from type A and B equipped by other certified applications provided that the EFB in question fulfils the requirements for these applications including a warranty that the uncertified applications cannot have malignant influence those that are certified. As an example for ensuring the independence between certified and other applications is a mechanism of robust formatting.

7. Software applications for EFB systems

7.1 Type A

Type A applications are those, whose failure or incorrect use does not have an influence on safety. Additional characteristics:

- can be used on portable as well as on built-in EFBs,
- do not require certification,
- have to be in line with the appendix D.[9]

Application examples:

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[7] Starr, A., Hoogeboom, P., *Future trends in flight deck equipment*. Springer-Verlag Berlin Heidelberg. 2007. Civil Aviation Authority of New Zealand, *Electronic Flight Bags*, In Vector 2012.

[8] Joint Aviation Authorities, TGL 36. Approval of electronic flight bags, 2004.

[9] Appendix D gives a detailed analysis of human – machine interaction from the Human Factor perspective. It provides various requirements for EFB (e.g. text readability under all lightning conditions, method of crew warning in case of malfunction of any part of EFB etc.).

- certificates and documents displayed by a browser (e.g. Registration Certificate),
- interactive applications (e.g. crew rest calculator).[10]

7.2 Type B

Type B applications are those, whose failure or incorrect use can cause a minor malfunction and those that by any means do not substitute or replace any system or function required by the regulations of the air space and operational regulations.[11]

Additional characteristics:

- can be used on portable as well as on built-in EFBs,
- require operational examination,
- do not require to be included in Airworthiness Certificate.

Application examples:

- handbooks and documents displayed in browser (e.g. Operating Handbook),
- electronic aeronautical charts with options to zoom, scroll, turn, centre etc., however without indication of aircraft's position (e.g. approach, sectional, aerodrome aeronautical charts),
- applications that indicate the position of the aircraft in real time (AMMD),
- applications that utilize internet or other aeronautical communications for reception, processing and distribution of data (e.g. information about unscheduled maintenance),
- applications utilizing algorithms for calculation of flight parameters (e.g. take-off runway calculations, aircraft weight and balance).[12]

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[10]Kratochvil, P., *EFB - Electronic Flight Bag*, In flyMag [online] 2013 [cit. 2014-5-3] http://www.flymag.cz/article.php?id=9208 (date of access: May 10, 2014).

[11] European Aviation Safety Agency, *Acceptable Means of Compliance*, 20-25, 2014.

[12] Stallings, W., *Operating Systems: Internals and Design Principles*, Pearson Education Inc. 2012, p. 769.

European Aviation Safety Agency, Acceptable Means of Compliance and Guidance Material to Part-CAT, 2012.

7.3 Complementary applications

Complementary applications are those that do not directly relate to EFB or activities of flight crew.

8. Legislation related to usage of multimedia devices on board

Legislative background for usage of EFB in Europe goes back to year 2004 when the list of temporary directives TGL 36 was issued. This document defined the characteristics of devices, their system equipment as well as the method of their usage. However this document had predominantly informative function and not binding character. This has changed on February 2nd, 2014 when, by the decision of EASA 2014/001/R, acceptable means of compliance demonstration AMC 20-25 came into effect. These fully cover the issue of EFB and its usage on-board the aircraft.[13]

9. Usage of EFB during VFR flight

Flight under visual meteorological conditions (VMC) is a flight whose necessary condition is the visibility of the ground because the navigation is carried out primarily by visual reference. Task of the EFB during a VFR flight is therefore not a provision of navigational information for the pilot according to which he will carry out the flight. Pilot is however able to quickly verify the flown track in case his device is equipped with a GPS receiver and a corresponding application. The most valuable contribution of EFB for a pilot will be in the phase of pre-flight preparation or in the phase of flight analysis. Prior to every VFR flight the pilot has to gather and evaluate significant amount of information such as meteorological information, flight route, fuel consumption calculations, weight and balance calculations, etc. Exactly for this flight phase the EFB tablet provides the ideal solution because it can gather and provide all abovementioned information. Nowadays a large number of devices and applications covering needs of complete VFR flight are available on the market.

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[13] European Aviation Safety Agency, Certification Specifications and Acceptable Means of Compliance for Large Aeroplanes CS-25, 2011.
European Aviation Safety Agency. *Acceptable Means of Compliance and Guidance*, Material to Part-ORO, 2012.

10. Analysis of available devices, applications and accessories on the market
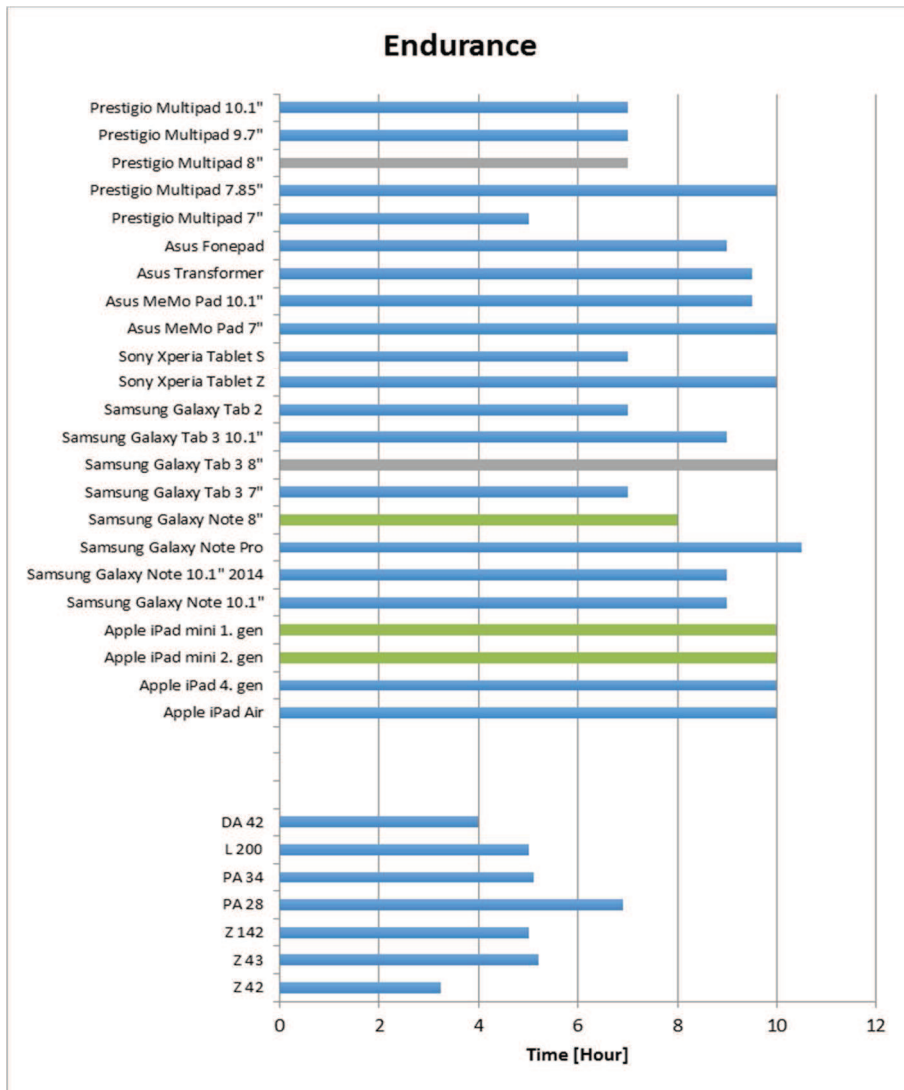
Currently a wide spectrum of various devices that fulfil the requirements for EFB functions exist. Multiple producers supply a range of smartphones and tablets in different price categories. For VFR flight the most suitable option is a tablet which thanks to its large display and high performance provides a wide range of possible uses. Two most dominant operating systems are iOS and Android. For both platforms a wide range of aviation applications exists.

For evaluation of individual devices we utilize analytical method supplemented by a comparison of devices based on technical specifications and price. The analysis considered 21 different tablet models from different producers (Figure 18). Parameters that had an influence on final assessment were the following:

- display resolution,
- display size,
- processor performance,
- application support and OS stability,
- battery life.

The analysis showed that Apple and Samsung tablets proved to be the most suitable. They are equipped with superior displays with sufficient resolution. Samsung tablet series Galaxy Tab offers devices with Android operating system that are affordable and of excellent built quality. They are therefore very popular among users as they are powerful enough and cost effective. Battery life is 7 to 10 hours which is sufficient for in-flight use.

Figure 18 .Tablet battery life and endurance of aircraft used in pilot training in the Flight School University of Žilina.

Source: Authors' own work

Regarding the accessories we were reviewing and analysing stands and knee pads that are necessary for fitting the tablets in the cockpit. All used devices had to fulfil requirements for safe mounting in the cockpit. From other accessories we focused on charging options through a mains socket of the aircraft as well as the possibility to utilize external battery.

11. Software equipment of tablets and EFB

Operating systems iOS and Android have several integrated applications that are utilizable in the aviation. For example compass, calculator or current location indication. However there are many other specialized applications that are specifically designed for use in the aviation. In the following paragraph we will analyze a few selected applications, their features, availability and price. Air Navigation application offers a bundle of several useful functions for use in VFR flight. It offers integrated database of basic charts which can be extended for a fee. Database includes all air spaces for given area (TSA, TRA) with depicted boundaries on the map. Very useful are information regarding airports such as elevation, runway system or all corresponding frequencies. During flight it provides the pilot with his current position. Pilot can also select to view other information such as ground speed, heading or alternatively classic analogue Horizontal Situation Indicator (HSI). Obviously it can provide function "Direct – To" which draws a shortest route to the destination on the map.

12. Requirements for portable electronic devices for flight school

In this part we will analyse the possibilities of usage of portable electronic devices for usage in flight schools. We will discuss basic requirements in the process of suitable model selection i.e.:

- hardware equipment,
- operating System,
- display size.

12.1. Device hardware equipment

One of the most important features for our needs is connectivity. Nowadays all tablets have access to the network via Wi-Fi, however only a few are equipped with data modem and allow connection to the network without Wi-Fi availability. Data transfer is not inevitable condition for usage of tablet for VFR flights purposes, however it brings a valuable advantage in possibility to obtain METAR messages any time as well as possibility to determine exact position in cooperation with GPS module. For Air Training and Education Centre (ATEC) the most advantageous option would be a device with 3G/4G modem. Requirement of internal memory capacity of at least 32GB stems from

the need to store large data files such as maps. Therefore the option of 16GB that majority of devices is equipped with, is insufficient for comfortable coverage of the EU region.

12.2 Operating system

Prior to selection of a suitable device it is necessary to determine the priority of operating system. In case of iOS and Android it is not that easy. In the past the Android has suffered stability issues which the iOS was able to exploit and established itself as stable OS. Currently both systems are fairly comparable in all aspects. According to the latest research the Android version 4.0 and higher are even more stable than iOS. According to the research carried out by Crittercism on one billion devices the probability of failure of Android 4.0 Ice Cream Sandwich, 4.1 – 4.3 Jelly Bean and 4.4 KitKat was only 0.7%. On the other hand the probability of failure of iOS 7.1 was 1.6%.

12.3 Device display size

Another important aspect in the selection process that it is necessary to consider is the display size. Devices on the market are available in various diagonal sizes of the display ranging from 7" to 12.2". This presents a wide range of options as the difference between the smallest and the largest display is 13cm in diagonal. If we consider VFR flights we need a device that can under all conditions display relevant information clearly and at the same time it will not interfere with activities of the crew. The device will be primarily used to display static data such as METAR messages. For this purpose a device with smaller dimensions is sufficient. To display charts a larger screen would be required. Nevertheless, the integrated browsers as well as stand-alone chart applications have a zoom function which enables comfortable portrayal of charts even on smaller screens. From the evaluation we can conclude that for the purposes of VFR flights a device with diagonal screen size of 8" would be the most suitable.

Conclusions

Preliminary research outcomes suggest that automation in the aircraft cockpit environment undoubtedly increases flight safety. It supports pilots' strengths and manages pilots' weaknesses. The automation significantly eliminates errors caused by human factor. On top of that, the

cockpit automation is being developed by the world's top experts. The trend of aviation surely shows the need for even further increase of cockpit automation. The results of the survey imply that even within airline pilot training environment, "the 70:20:10 Model for Learning and Development" is valid. (70% means real experience, 20% means social interaction with colleagues, 10% is formal education). One needs to be aware what the automation does, how it should be used, and how to benefit from it as much as possible without compromising safety and knowledge and skills of pilots. Xunzi (Confucian scholar) said: *Not hearing is not as good as hearing, hearing is not as good as seeing, seeing is not as good as knowing, knowing is not as good as acting; only when a thing produces action can it be truly learned.* Popularity of multimedia portable devices has been increasing since their introduction. Modern tablets have become an everyday part of our lives and they found their application in many industries. Aviation is one of them. Tablet can significantly ease the work of pilot. This paper analysed basic parameters and requirements for equipping flight schools with tablets or more precisely EFBs and covered all key areas that relate to the issue of usage of portable multimedia devices for VFR flights and in flight schools. The authors reached a conclusion that equipping the aircraft with tablets would bring several advantages including increase in safety. Safety is the single most important factor in air transport and within the context of flight school its level is an indicator of quality. Usage of tablets could help divert dangerous situations such as flight of students into the restricted areas during solo flights. Equipping the aircraft with tablets would also increase the image of the flight school towards the public and it would be a clear sign that the flight school follows modern trends and it is trying to implement them into its operations. Usage of tablets would also help the instructors and students to adapt to touch screen controls that the producers of avionic systems are starting to use and we can also expect that in relatively short time these systems will form standard equipment of aircraft used in general aviation.

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