

ČESKÉ VYSOKÉ UČENÍ TECHNICKÉ V PRAZE

FAKULTA DOPRAVNÍ

Pavel Brodský

DOPORUČENÍ PRO ZAVÁDĚNÍ EFB Class II

Bakalářská práce

2015



ČESKÉ VYSOKÉ UČENÍ TECHNICKÉ V PRAZE

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- Úvod
- Popis EFB
- Výhody a nevýhody EFB Class II
- Právní úpravy a standardní provozní postupy (SOPs)
- Dopstupná softwarová řešení
- Finanční analýza, vzorové situace a očekávané výsledky
- Shrnutí a doporučení
- Závěr

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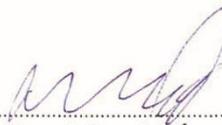


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- EFB description
- EFB Class II advantages and disadvantages
- Legal Requirements and standard operating procedures (SOPs)
- Available software products
- Financial analysis, model situations and expected drawbacks
- Summary and recommendation
- Conclusion

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I confirm assumption of bachelor's thesis assignment.



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Prague October 24, 2014

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Předkládám tímto k posouzení a obhajobě bakalářskou práci, zpracovanou na závěr studia na ČVUT v Praze Fakultě dopravní.

Prohlašuji, že jsem předloženou práci vypracoval samostatně a že jsem uvedl veškeré použité informační zdroje v souladu s Metodickým pokynem o etické přípravě vysokoškolských závěrečných prací.

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V Praze dne 20. srpna 2015



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ČESKÉ VYSOKÉ UČENÍ TECHNICKÉ V PRAZE

Fakulta dopravní

DOPORUČENÍ PRO ZAVÁDĚNÍ EFB Class II

bakalářská práce
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Pavel Brodský

ABSTRAKT

Předmětem bakalářské práce „Doporučení pro zavádění EFB Class II“ je analyzovat současný stav užívání elektronických zařízení namísto tradičních papírových dokumentů na palubách dopravních letounů a na základě této analýzy vypracovat doporučení případným dalším provozovatelům, jestli na tuto technologii přejít, které produkty vybrat, a jakou finanční náročnost očekávat.

Klíčová slova: Electronic flight bag, e-charts, Jeppesen, LIDO, Navtech

ABSTRACT

The subject of the bachelor thesis „Recommendation for EFB Class II Implementation“ is an analysis of present state of using electronic devices instead of traditional paper documents on board of transport aircraft. Based on this analysis a recommendation for other operators will be created to advise whether to switch to using this technology, which platform to choose and expected costs of this solution.

Key words: Electronic flight bag, e-charts, Jeppesen, LIDO, Navtech

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1 List of used abbreviations

AAC	Airline administration communication
ACARS	Aircraft Communications Addressing and Reporting System
ADC	Aerodrome Chart
AID	Aircraft Interface Device
AIP	Aeronautical Information Publication
AMC	Acceptable Means of Compliance
AOC	Airline operational communication
APC	Air passenger communication
ARINC	Aeronautical Radio, Incorporated
ATIS	Automatic Terminal Information Service
CAA	Civil Aviation Authority
CAT	Clear Air Turbulence
CB	Cumulonimbus
COTS	Commercial off-the-shelf
CRM	Crew Resource Management
DOA	Design Organization Approval
EASA	European Aviation Safety Agency
ECL	Electronic Checklists
EFB	Electronic Flight Bag
EMI	Electromagnetic interference
FAA	Federal Aviation Administration
FC	Fixed Costs
FCOM	Flight Crew Operations Manual
FMS	Flight Management System
HW	Hardware
IAC	Instrument Approach Chart
IFR	Instrument Flight Rules
JAA	Joint Aviation Authorities
MC	Minor Change
MDM	Mobile Device Management

NOTAM	Notice to Airmen
OCC	Operations Control Centre
OFP	Operational Flight Plan
POA	Production Organization Approval
PDC	Aircraft Parking/ Docking Chart
PED	Portable Electronic Devices
PF	Pilot flying
SID	Standard Departure Chart - Instrument
SIGMET	Significant Meteorological Information
SOP	Standard Operating Procedures
STAR	Standard Arrival Chart - Instrument
STC	Supplement Type Certificate
SW	Software
TA ČR	Technologická agentura České republiky
TAF	Terminal Area Forecast
TC	Total Costs
VC	Variable Costs
VFR	Visual flight Rules
VHF	Very High Frequency
VPN	Virtual Private Network

2 Introduction

In my bachelor's thesis I would like to focus on Electronic Flight Bags and their implementation in an airline environment. The goal of my thesis is to create a well arranged overview for a hypothetical airline which could use my thesis during the process of consideration if and how to implement EFB. My thesis is based on experience of ABS Jets which is an executive jet operator and Travel Service which is a charter airline.

The regulations mentioned in my thesis are those which apply to European operators regulated by EASA. Situation in countries regulated by FAA can be different and it will not be described in this thesis. Because of very wide variety of available EFB solutions I will focus only on EFB class II in my thesis – the portable devices which can be mounted in the cockpit and used during the whole flight.

In my thesis I would like to confirm or disprove that EFB can pay back to the airline in a horizon of few years. The thesis should also include rough estimation of various costs connected with EFB implementation and usage.

3 EFB description

According to JAR-OPS, the definition of an EFB is:

“(...) an electronic display system intended primarily for flight deck or cabin use. EFB devices can display a variety of aviation data or perform basic calculations (e.g., performance data, fuel calculations, etc.). (...) The scope of the EFB system functionality may also include various other hosted databases and applications. Physical EFB displays may use various technologies, formats, and forms of communication” (1).

Because of a wide variety of available EFB devices the EFBs are divided into three classes according to their hardware configuration (class 1, class 2 and class 3). Each class has different requirements on the installation, usage approval etc. Those aspects are described later on (1).

The software running on the EFB is divided into three types (Type A, Type B and Type C) according to how interactive and independent the application is. Types A and B have different requirements than Type C as described later on (1).

There is a wide variety of information which can be displayed on EFB devices from basic documents via interactive pilot oriented applications to complex software fully compatible with on-board avionics. Portable devices are also often used for other non-operational applications which meet the individual airline's need and which are not used during flight.

3.1 EFB classes' overview

Class 1 devices are portable COTS (Commercial-Off-The-Shelf) devices connected to aircraft power supply through a certified power source. They are not attached to the aircraft using any mounting device and do not communicate with the aircraft data busses (exceptions exist). Class 1 EFBs do not require any airworthiness approval (1).

Class 2 devices are very similar to Class 1 devices with exceptions that the EFBs are usually connected to aircraft mounting device which hold them in the place for the whole flight and that the EFBs can be connected to aircraft avionics (1).

Class 3 devices are installed in the cockpit by airplane or avionics manufacturer. They require airworthiness approval which must cover the hardware and software qualification (1).

3.2 EFB software types overview

Type A software are applications which provide information presented in paper form so far. This type of software doesn't need airworthiness approval but needs operational approval. These applications can be hosted on any of the hardware classes listed above. Typical examples of Type A software are: FCOMs, SOPs, flight logs, maintenance manuals, NOTAMs, AIPs, etc (1).

Type B software includes more advanced applications with dynamic and interactive content. The airworthiness and operational approvals are the same as for the Type A software. Typical examples of Type B software are: performance calculators, power settings, weight and balance calculators, aeronautical charts, airplane manuals with contextual access to aircraft parameters (FCOMs, checklists...) (1).

4 EFB Class II advantages and disadvantages

EFB Class II requires airworthiness approval to be issued for each installation. This can be considered as a disadvantage. On the other hand the approval is required only for the mounting device, crashworthiness of the EFB, data connectivity (if any) and power connection (which requires airworthiness approval even for Class I EFB). The actual PED doesn't require the approval to be issued for each individual device.

The biggest advantage is that Class II provides very good functionality usable during the whole flight for significantly lower price than Class III¹. Because of the mounting device the Class II hardware can be used during the entire flight which means no more paper charts need to be purchased and distributed to aircraft and all documents can be managed remotely from the airline base.

4.1 The process of airworthiness approval for EFB Class II

4.1.1 Mounting device

Mounting device attaches the EFB hardware to the aircraft. According to JAA Leaflet No. 36² the mounting device and the EFB should not restrict the crew when operating any system during normal, abnormal and emergency procedures. The EFB device should be easily locked in the mounting device and it should be possible to position the EFB according to individual preferences of any pilot. The mounting device should be designed that it keep its performance over time and will not become loose later. Crashworthiness should be considered in the way that the mounting device and the EFB would be appropriately resistant. The mount also needs to provide possibility to be locked out of way of pilot's operations when not in use. If the EFB is mounted on the side panel and the aircraft is controlled by side stick or if the EFB is mounted on the yoke the mounting device must allow full movement of the controls under all conditions. If the mounting device is located on the yoke the operator needs obtain Original Equipment Manufacturer (OEM) data to show that the increased inertia of the yoke has no effect on the aircraft handling qualities. The cables connecting the EFB to the aircraft systems can run either inside of the mounting device or outside. If they run outside they should not hang loosely in a dangerous way. The crew must be able to secure the cables (e.g. with the tether strips). The cables length must also be taken into consideration to ensure that the cables are not either too long or too short where both of those cases could cause hazard (1).

¹ According to ABS Jets, up to 115 000 CZK per year

² Chapter 6: Airworthiness Approval

4.1.2 Placement of the mounting device

When the EFB is intended to be used it should be located within 90 degrees from the pilot's line of sight except for situations where the EFB isn't intended to be monitored during the flight (e.g. doesn't contain charts and is used only for performance calculations during the pre-flight phase). On the other hand even the 90 degrees angle can be unacceptable for those EFBs which have displays with worse monitoring angles. Also the possible confusion resulting from misinterpreting information given by the EFB which needs to be relative to the aircraft heading (e.g. traffic display) (1).

4.1.3 EMI demonstrations, lithium batteries, power source and data connectivity

The data connectivity of the EFB needs to be evaluated to ensure that there is no interference between the EFB and the aircraft systems.

EFB Class II devices are intended to be used during critical phases of flight (take-off and landing), which means that the EMI testing has to be done (either at laboratory, on the ground, or during test flights). EFBs have to comply with document ED-14()/DO-160() Section 21, Emission of Radio Frequency Energy (1).

Lithium batteries inside the EFBs are potentially dangerous and need to be certified to certification standard UL 1642 for possible leakages and the on-board storage for spare batteries and continuous charging should be evaluated (1).

The power source design must allow the power source to be disconnected either by unplugging the EFB, or by on/off switch. The switch must not be substituted by a circuit breaker. Installation of a secondary power source for powering the EFB may be required (1).

4.1.4 Operational approval process

Document EASA AMC 20-25 is taken into account in the process of certification. This document includes information from previously used JAA Leaflet No. 36 and EASA NPA 2012-02.

The AMC 20-25 further specifies related documents and guidance materials (for example Certification Specifications, Commission Regulations, AMCs, and FAA regulations for non-European operations with EFBs).

Following Table 1 is an overview of evaluations required for various EFB parts (2).

Table 1: the EFB certification requirements (AMC 20-25)

EFB constituent		Portable EFB		Installed EFB	
		Assessment	Records or approvals	Assessment	Records or approvals
HW	Installed resources and mounting device	EASA Airworthiness approval		EASA Airworthiness approval	
	EFB host platform	Evaluation	Operations manual amendment	EASA Airworthiness approval	
SW	Miscellaneous software	Operator Evaluation	Operations manual amendment	Operator Evaluation	Operations manual amendment
	Type A	Operator Evaluation	Operations manual amendment	Operator Evaluation	Operations manual amendment
	Type B	Evaluation	Operations manual amendment	Operator Evaluation	Operations manual amendment

Evaluation represents hardware operational assessment. This process includes (2):

- EMI demonstrations: operator’s responsibility to perform or obtain from aircraft type certificate. Recommended methods are further described in the AMC 20-25.
- Batteries: operator’s responsibility to determine usability of the batteries. Relevant sources of performance standards are listed in the AMC 20-25.
- Power source: requirement on EFB design to ensure independence of power sources
- Environmental testing: operator’s responsibility to ensure that either the HW platform was tested, or that the EFB failure after rapid depressurization is acceptable
- Display characteristics: requirement on EFB design to ensure that the EFB is not an obstruction in external view, the display location is appropriate, glare and reflection do not interfere with normal operations, that the EFB is legible, the backlight is dimmable.

- Stowage characteristics: requirement on EFB design to ensure that the EFB is stowed securely to avoid jamming flight controls, damaging flight deck or injuring crew members in case of sudden movement of the aircraft (turbulence or manoeuvring).

Operator Evaluation represents requirements on software applications – they don't require operational approval, but the human factors shall be assessed according to AMC 20-25. Some (in the AMC 20-25 listed) applications require documented evaluation that shall be performed. The non-EFB software applications should be assessed by the EFB administrator to avoid any impact on the EFB (2).

Operations manual amendment – as described under Chapter 5 Legal Requirements and standard operating procedures (2).

EASA Airworthiness approval covers (2):

- Mounting device (as described in chapter 4.1.1 above)
- Placement of the display and its characteristics
- Power source
- EFB data connectivity (if any wired or wireless)
- Connecting cables

4.1.5 Changes to EFB

The modifications may be required during the EFB life. They can be divided into two groups – those that need to be reported to the authority, and those that have to be approved by the authority.

Following changes can be done by the operator without authority (CAA) action. They, however, need to be tested prior to use (2):

- Changes to Type B applications that do not change the algorithms
- Installation or modifying any Type A applications
- Updating database to Type B applications.
- Operating system updates
- Updates or fixes to existing applications

4.1.6 The EFB administrator

EFB administrator is a person responsible for the EFB system by the individual operator. As described in the AMC 20-25, the EFB administrator responsibilities are (2):

- Managing all applications and providing user support
- Ensuring security of EFB
- Checking authorisation of user installed software, HW and SW configuration
- Checking version validity and database versions
- Ensuring integrity of data packages

4.1.7 Crew training

The crew must be trained to use EFB. Following list mentions the minimum requirements for crew training (2) (cited from AMC 20-25):

- *An overview of the system architecture;*
- *Pre-flight checks of the system;*
- *Limitations of the system;*
- *Specific training on the use of each application and the conditions under which the EFB may and may not be used;*
- *Restrictions on the use of the system, including where some or the entire system is not available;*
- *Procedures for normal operations, including cross-checking of data entry and computed information;*
- *Procedures to handle abnormal situations, such as a late runway change or diversion to an alternate aerodrome;*
- *Procedures to handle emergency situations;*
- *Phases of the flight when the EFB system may and may not be used;*
- *CRM and human factor considerations on the use of the EFB; and*
- *Additional training for new applications or changes to the hardware configuration.*

5 EFB back-office and avionics connectivity

5.1 Avionics connectivity

Some EFB may be able to communicate with aircraft avionics busses. The aim of these connections is a two-way exchange of data between EFB and FMS, position information from FMS to EFB, maintenance related parameters download, and ACARS communication. The EFB can also connect to aircraft communication channels in order to send data to back-office (3).

The EFB Class I are now not allowed to communicate with aircraft avionics. However company Teledyne Controls is developing a device to connect Class I EFB with aircraft busses (3).

EFB Class II can communicate to aircraft avionics using AID. The AID is a device that connects to ARINC 429 data bus (which is a commonly used bus connecting various aircraft avionics). The AID then sends data obtained from ARINC 429 bus to the EFB – either using wired Ethernet connection, or using WiFi or Bluetooth hotspot. Data from EFB can be transferred to AID and converted to ARINC 429 format (for example performance data uplink from EFB to FMS) (3) Example of AID is shown on following Figure 1.



Figure 1 UTC Aerospace AID (image from ainonline.com)

Class III EFB are part of aircraft avionics and are usually connected to busses (for example ARINC 429). This means they can exchange data with avionics directly, without any need for AID (3).

Many vendors, who used to develop their own specialized EFBs, now provide AID to connect COTS EFBs with aircraft avionics. Examples of those vendors are navAero, Astronautics, CMS Electronics, UTC Aerospace and DAC International (3).

5.2 Back-office connectivity

Back-office connectivity generally means the ability to communicate between EFB and airline OCC, or airline ground workers generally.

There are three types of communication categories related to back-office connectivity (3):

- AOC: airline operational communication
- AAC: airline administration communication
- APC: air passenger communication

These communication categories are not critical for safety of the flight. An example of AOC communication is sending live weather updates or flight plan updates. AAC messages includes updating libraries and databases (of electronic charts, manuals, or forms) (3).

The main technologies for sending data between airline ground station and EFB are ACARS and internet. While internet connection can be accessed from most of EFBs, the ACARS communication is only done using the aircraft systems thus requiring EFB to be connected to the ARINC bus (3).

The ACARS itself can be done either using the VHF datalink (either analogue or digital) or satellite communication. The main difference between ACARS and internet connection is that ACARS is widely available, but much slower compared to internet (speeds vary between 2.4 kilobits per second for satellite communication, up to 31.5 kilobits per second for digital VHF communication) (3).

When on the ground, many airlines use cell phones to create WiFi hotspot to connect EFBs to the internet, or when using portable EFB the data transfer can be performed outside of the aircraft cockpit. Some airports feature Gatelink WiFi which provides WiFi access in each gate for EFBs. The disadvantage of Gatelink WiFi is high cost for the airport operator (3).

5.3 Cost of EFB to ground communication

The ground based data transfer is generally cheaper than using ACARS. The ACARS cost are difficult to determine, because the costs over VHF are based on number of characters send, but the satellite communication is paid for amount of data transferred. The newer Boeing and

Airbus aircraft have the capability to select the cheaper ACARS method when both VHF and satellite communication is available (3).

5.4 EFB connectivity case studies

5.4.1 American Airlines

American Airlines operates with iPad Class I EFBs. FAA approved American Airlines to operate with Class I EFB during all phases of the flight. Their iPads run Jeppesen e-charts and a document viewer GoodReader with built-in document management. American Airlines don't use connection to aircraft avionics. WiFi and cellular connection is used on the ground at the company bases (3).

5.4.2 Croatia Airlines

Croatia Airlines was switching from Class I to Class II EFB in 2014. Their Class II is based on Samsung PC notebooks convertible to tablets by removing the keyboard. These computers run Windows 7. NavAero holders are used to mount those devices. Croatia Airlines use Lido/eRoute Manual with e-charts. In the future their EFBs will be used also for performance calculations. The airline doesn't plan to connect the EFBs to the avionics busses. Ground based WiFi and cell phone (using the SIM card inside the Samsung computer) connection is used (3).

5.4.3 Thomson Airways

The Thomson Airways uses the EFB Class III in their Boeings 787 supplied by the aircraft manufacturer. Other than B787 planes in their fleet use Class II EFB by navAero which are wired to an AID and further to aircraft avionic busses. The data are sent only from EFB to the aircraft, not backwards. Thomson Airways use Jeppesen e-charts in their Class II EFB. Their Class III EFBs are connected to ACARS over VHF or via satellite communication (3).

6 Legal Requirements and standard operating procedures

In the process of CAA certification, following documents are mandatory³:

- EFB Policy Manual
- Chapter about EFB operations in the company Operations Manual
- Supplementary Type Certificate

EFB Policy Manual is a document that describes the technical parameters of the EFB that are used. Usually this documents describes hardware platform description and operating limits, software configuration and classification and information about HW and SW administration (how technically are the updates done, who can do HW and SW updates, which maintenance is required).

Operations Manual is a document describing all procedures related to operating a flight by a given company. When the company is implementing EFB into its operations, it must be described in the Operations Manual. Usual content of the EFB chapter in the OM is a brief description of EFB HW and SW, location of the EFB inside of the cockpit, charger, updating procedure flight procedures and EFB failure procedures.

Recommended SOP for the EFB operations will be described based on the data provided by Travel Service for their iPad Class II EFBs. The hardware EFB must be placed either in the certificated holder during all phases of flight, or in aircraft without the holder or with the holder inoperative the EFB can be used outside the holder, but only outside the critical phases of flight. The pilot is required to bring the EFB (iPad) charged for at least 60% before the flight (except for the planes with chargers included in holders). The EFB database must be updated before the first flight of the day, during the briefing and the database versions must be cross-checked between pilots. During pre-flight, both crewmembers must do the performance calculations independently and then compare the results. The e-charting application must be checked for updates after launching it and all the departure charts must be ticked as “favourite” before flight (4).

According to L-8168, operators have to implement checklists as an inseparable part of SOPs. Checklists should describe list of actions related to the specific phase of flight that have to be done or checked by the crew (...). Checklists should also provide directions to check aircraft and systems configuration that avoids human factor related mistakes (5).

There is a Travel Service pre-flight checklist that should be done before EFB usage. This checklist contains following items (4):

³ Based on Travel Service sample data and AMC 20-25

BATTERY LIFE	Adequate
DATABASE	Current
AIRPORTS AVAILABILITY	Checked
AUTOLOCK	10 min
PASSCODE LOCK	OFF
DATE and TIME	CORRECT
AIRPLANE MODE	ON

During taxi, pilots shall have displayed appropriate airport/taxi charts. During departure, both crewmembers should display SID chart. Enroute phase should be flown with enroute chart with current route displayed on the PF EFB. Before commencing approach briefing, both crewmembers should mark all the arrival charts as favourite in their EFBs. Landing performance should also be computer independently on both EFBs and results should be compared (4).

Dispatching and operating with not fully working EFB is also possible. If one or both EFB holders are inoperative, the aircraft must be fitted with one or two copies of terminal charts. This ensures that the hand held EFB will be used only during enroute phase of flight. If EFB device fails before flight, the flight can be operated with paper documentation on board. If the EFB fails during the flight, the rest of flight is operated with one EFB only. In the event of both EFB failure during flight, the crew has a paper form that helps to obtain required information for approach from ATC (approach parameters, minimums, etc.) (4).

6.1 EFB certification

Following information were kindly provided by Czech CAA.

Commission Regulation 748/2012 supplement I PART21 SUBPART D — CHANGES TO TYPE-CERTIFICATES AND RESTRICTED TYPE-CERTIFICATES; SUBPART E – SUPPLEMENTAL TYPE CERTIFICATES defines legal steps required for any changes being done on EASA certified aircraft (not only EFB mounting, but generally any modifications). For Czech registered aircraft, this policy is defined by regulation L8/A.

Technical changes to aircraft construction and systems (including EFB mounting device) installation can be performed by DOA, POA, PART66 and PART 145 organizations.

Before performing any modification, the relevant materials have to be provided to CAA (including proposed modification description and flight manual changes). After the CAA

approval is obtained, the modification can be performed. CAA has no legal way how to approve modification that was done without prior notification retrospectively.

Materials provided to the CAA must include:

- Classification of the modification (major/minor)
- Change examination request
- Team which will perform the modification
- Modification description
- Certification programme description
- Required analysis
- Block diagrams (if any)
- Proof of legal origin of used parts
- Methodology and results of laboratory/ground/flight tests
- Certificate of Conformity
- Evidences of compliance with relevant regulations
- Overview of fulfilling requirements
- Flight manual and maintenance manual amendment
- List of project documents

7 Available software products

There are various software solutions available for EFBs – starting at electronic chart applications from traditional chart providers, performance applications like weight and balance calculators, runway analysis software, take off performance calculators, flight planning software for OFPs, NOTAM or company briefing viewers, up to generic tablet applications like PDF viewers, remote device management utilities or office applications.

7.1 Charts software

7.1.1 Jeppesen products

Jeppesen is an American company founded at 1934 that specializes in navigational information – especially providing worldwide charts and weather information for aviation and marine. The company started with production of paper printed charts that are still available, but now also offers wide variety of electronic charts. Following text contains basic overview of available products by Jeppesen.

Mobile FliteDeck VFR is an iPad application for general aviation usage focused on VFR navigation. This application features a moving map with location of own aircraft displaying airspace, airports, basic terrain and navigational data. FliteDeck VFR is also capable of downloading weather information and NOTAMS (6).

Mobile FliteDeck is an iPad application for IFR navigation. In this application there is an enroute chart module capable of being configured for displaying lower or upper airspace airways and a terminal charts module for displaying airport-related charts – ADC, PDC, SID, STAR, and IAC charts. FliteDeck is able to download METARs. Charts in FliteDeck are updated with every AIRAC cycle and also in weekly minor updates. Another feature of FliteDeck is ability to download Jeppesen route manuals for individuals regions as well as any company manuals. All those manuals are displayed using iPad PDF viewer that is installed on the device (for example Adobe Reader) (6).

Mobile FliteDeck is available under two licences – one for General Aviation IFR pilots, and one for Business Aviation IFR pilots.

Example of IAC chart displayed in FliteDeck is shown in Figure 2 (bellow).

Mobile TC is the Jeppesen's only Android application. Mobile TC is an Android tablet application that is very similar to FliteDeck for iPads. The only difference is that Mobile TC displays only terminal charts (ADC, PDC, SID, STAR, and IAC) as there is no module with enroute charts. This application is updated in the same way like the FliteDeck. Due to wide variety of Android tablets on the market this application is limited only to Samsung Galaxy tablets (6).

FliteDeck Pro is the most advanced of Jeppesen applications. This solution is available both for Windows and iOS platforms. The basic functionality of FliteDeck Pro is similar to Mobile FliteDeck, but the extra features are: FAA-approved Airport Moving Map, AirWatch service intended for remote management of mobile devices across the entire fleet, device tracking and integrated eMail module. This application is intended for commercial and military aviation users (6).

Apart from that, Jeppesen offers desktop Windows PC applications JeppView for printing and viewing charts and FliteStar for flight planning. One more product from Jeppesen is iCharts – web browser based viewer of IFR charts similar to desktop JeppView (6).

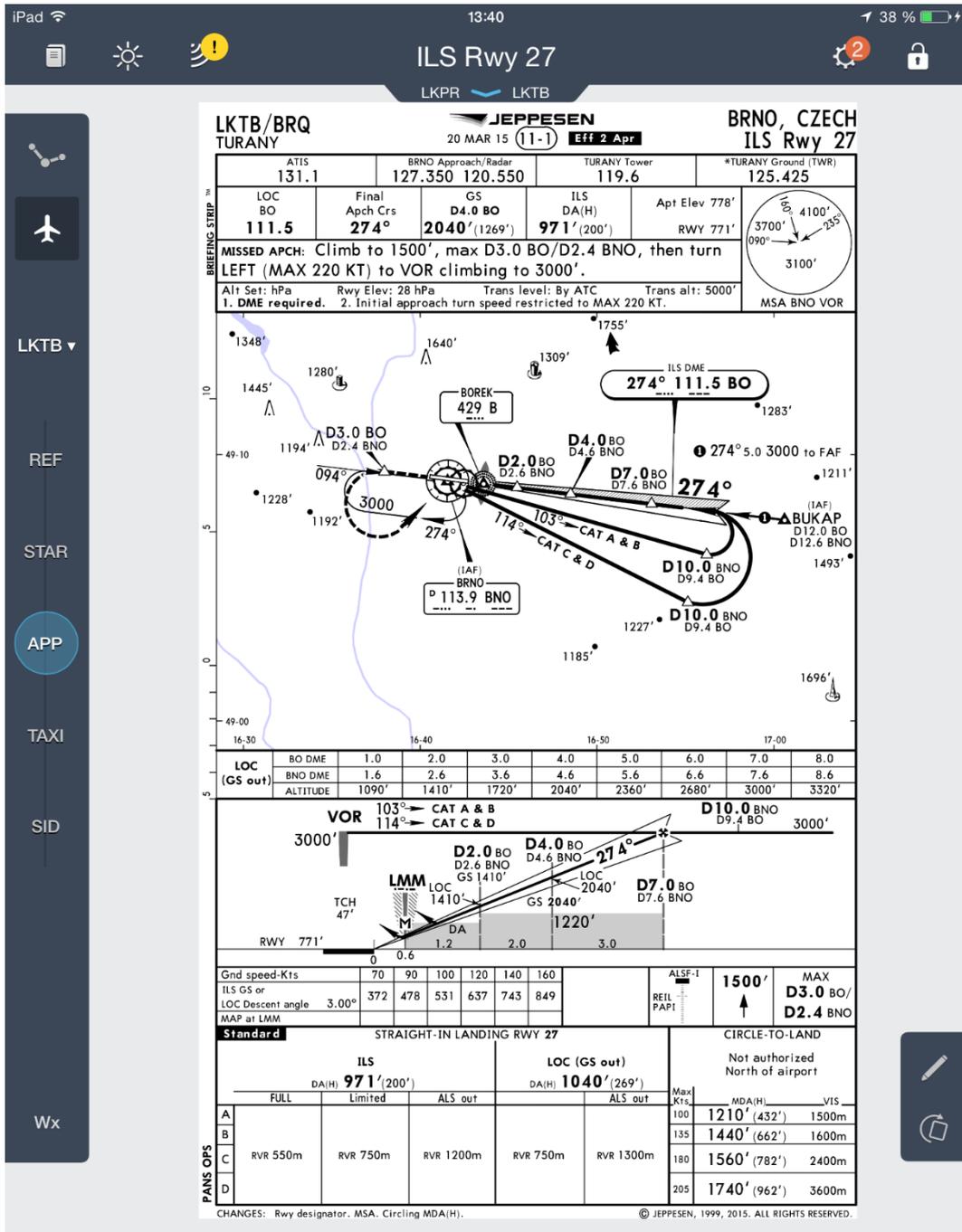


Figure 2: Jeppesen FliteDeck showing IAC chart (screenshot from ČVUT FD iPad).

7.1.2 Lufthansa Systems products

Lufthansa Systems is a German IT company founded in 1995 as a partner company of Lufthansa (originally named LIDO). This company offers variety of IT products both for mobile and for desktop platforms. According to company website, the products can be divided into following groups:

- Operations solutions
- Commercial solutions
- Flight Deck solutions
- Finance Solutions
- In-flight entertainment
- Mobile Cabin Solutions

Operations solutions is a group of applications intended for operations control centres (OCC) and includes tools for schedule planning, crew planning, financial tools, aircraft loading, airline hub organization and flight planning (7).

Commercial solutions feature tools for management and scheduling, revenue management and pricing, marketing and sales (7).

Finance Solutions are tools of Sirax family intended for reporting, analysing and controlling airline financing and invoicing (7).

In-flight entertainment category includes BroadConnect application that includes software for on-board WiFi network that streams in flight movies, music and other content both to devices integrated in passenger seats and to portable devices that belong to passengers (tablets, smartphones...) (7).

Mobile Cabin Solutions is a category with a single product – mCabin – that is a tablet application for cabin crew including duty planning, briefings, list of cabin crew members, list of passengers and reporting tool (7).

Flight Deck Solutions are two products intended for crew devices/tablets. They are: Lido/Performance and Lido/Navigation and. Further description of those three products follows (7).

Lido/Performance is a tool mainly aiming on take-off performance calculation based on weight, runway, obstacles and meteorological data. Lido/Performance is further subdivided into three subsections that are represented by individual applications. They are: Lido/TakeOff, Lido/ObstacleData and Lido/APM (7).

Lido/TakeOff is a multi-platform application capable of calculating take-off parameters as V speeds, flap settings, limiting weight, stop margin, thrust level and assumed temperature, acceleration altitude, limiting factors and engine failure departure procedure based on input parameters (weather information, weights, air condition, anti-icing, runway database) (7).

Lido/ObstacleData is a database containing information for each individual airport including obstacle information, NOTAMs and EOSIDs (7).

Lido/APM is an Airplane Performance Monitoring solution in a web based application that monitors a real fuel usage for each individual aircraft in a fleet. Key benefit of APM is a data collection from each aircraft that allows further more precise fuel calculation in a process of flight planning (7).

Lido/Navigation is a set of six services: Lido/RouteManual, Lido/eRouteManual, Lido/mPilot, Lido/AMM, Lido/AMDB and Lido/FMS (7).

Lido/RouteManual is a subscription based service of paper charts. Lido/RouteManual includes both enroute and terminal charts that can be delivered either for each pilot, or for each aircraft of an airline (7).

Lido/eRouteManual is a windows based application with electronic charts. The aim of this application is to provide the same content as Lido/RouteManual does, only in electronic form. The application includes both enroute and terminal charts and directly cooperates with Lido/AMM (7).

Lido/mPilot is a set of three modules for iPad tablets. This application is the EFB solution for displaying charts and documents. Lido/mPilot includes: Terminal module, Enroute module and Documents module. Terminal module includes airport related charts, Enroute module includes worldwide IFR enroute map. Documents module is a tool for synchronizing company documents across all portable devices and for company messaging. Example of a colourful IAC chart is shown in Figure 3 (7).

Lido/AMDB means Airport Mapping Database that provides geo-referenced representation of airports in Lido/AMM application and in Lido/eRouteManual (7).

Lido/FMS is a FMS update service including airport, airways, waypoints, nav aids, and procedures information for worldwide IFR airports. The database is also used for generating the Lido/RouteManual and Lido/eRouteManual which results in the same data being displayed on charts and in FMS. Lido/FMS database is updated with AIRAC cycles every 28 days (7).

7.1.3 Navtech products

Navtech is an international, originally Canadian company founded in 1980s. Navtech offers following IT services for civil aviation (8):

- Navtech Flight Plan
- Aircraft Performance
- Navigational Data
- Crew Planning

Navtech Flight Plan (NFP) is a web browser based tool for OCC flight planning purposes. Main features of this tool is a route searching and validation system, cost index optimization, ETOPS support, high resolution weather models and Flight Hazards prediction tool for turbulence and icing avoidance (8).

Navtech Charts are paper aerodrome and enroute charts for IFR flying. Except for standard IFR charts they feature plotting charts, fuel/gross weight charts, and route manuals. The same content is also available in electronic form for Class 1 and Class 2 EFBs based on iPads. Navtech version of IAC chart is shown in Figure 4 (8).

Navtech Navigation Data is a set of FMS updates for various avionics manufacturers. Data are updated every 28 days by an AIRAC cycle and are customisable for individual airline and aircraft type, including helicopters (8).

Navtech Crew Planning is a set of two tools – Navtech Preferential Bidding System (PBS) and Navtech Pairing Optimizer that aim to provide optimal crew schedules according to individual preferences (8).

7.1.4 Air Support products

Air support is a Danish company specializing in development of flight planning software for airlines, business aviation and military. The core product is an OCC flight planning tool which is capable of OFP creation. For EFB usage this company provides crewbriefing.com website that is used for downloading individual OFPs, NOTAMs, company briefings, AFM and other PDF documents into EFBs (9).

7.1.5 Boeing products

Boeing offers an integrated software utility for both Boeing EFB Class III and for iPad class II and I EFB called Boeing OPT (Onboard Performance Tool) (10). This utility allows the crew and ground personnel to do performance calculations including take off performance (thrust reduction, V speeds, flap settings), landing analysis (landing distance, autobrakes setting), and weight/balance calculations, all depending on environmental data, weight, aircraft configuration and equipment, and inoperative systems or devices on board. Boeing says, the results reduce operating costs of fuel, engine maintenance and makes ground dispatch quicker. Demo version of the Boeing OPT is available in Apple Store for free with data of fictional aircraft included. Following Figure 5 shows example of take-off calculation using this demo version.



Figure 5: Boeing OPT take-off performance calculation (screenshot from ČVUT FD iPad, demo version of the product).

The checklists look similar to checklists that Boeing uses in their newer types (B777, B787) in their ECL. The difference is that ECL (that are integrated in the aircraft avionics) can sense the state of each individual system or switch, but the iPad checklists in the Boeing OPT are not connected to the aircraft thus can only rely on that pilot clicks. Similarities of B777 ECL and iPad OPT can be seen on following two figures 6 and 7.



Figure 6 Boeing 777 ECL (image from flightdeckaction.com DVD movie)

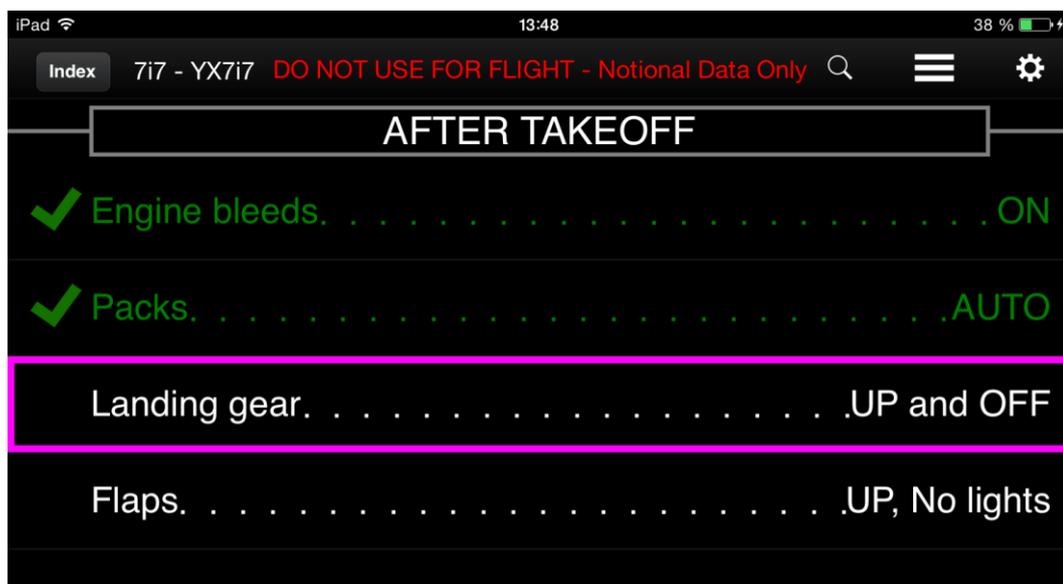


Figure 7 Boeing OPT checklists (screenshot from ČVUT FD iPad, demo version of the product).

7.1.6 Airbus products

Airbus provides their customers with FlySmart utility (member of the LPCNG software family). This utility has similar aim to Boeing OPT – it provides the flight crew with a performance calculator for Airbus fleet. The FlySmart consist of individual modules – Landing, Take off and PDF document viewer. The application includes its obstacle database which can be updated together with the documents for viewer anytime when the iPad is connected to WiFi network. The FlySmart is developed exclusively for iPad and is not available to any other tablet platform

(11). The full version of FlySmart is available only to Airbus customers. Figure 8 shows weight and balance shown in FlySmart interface.

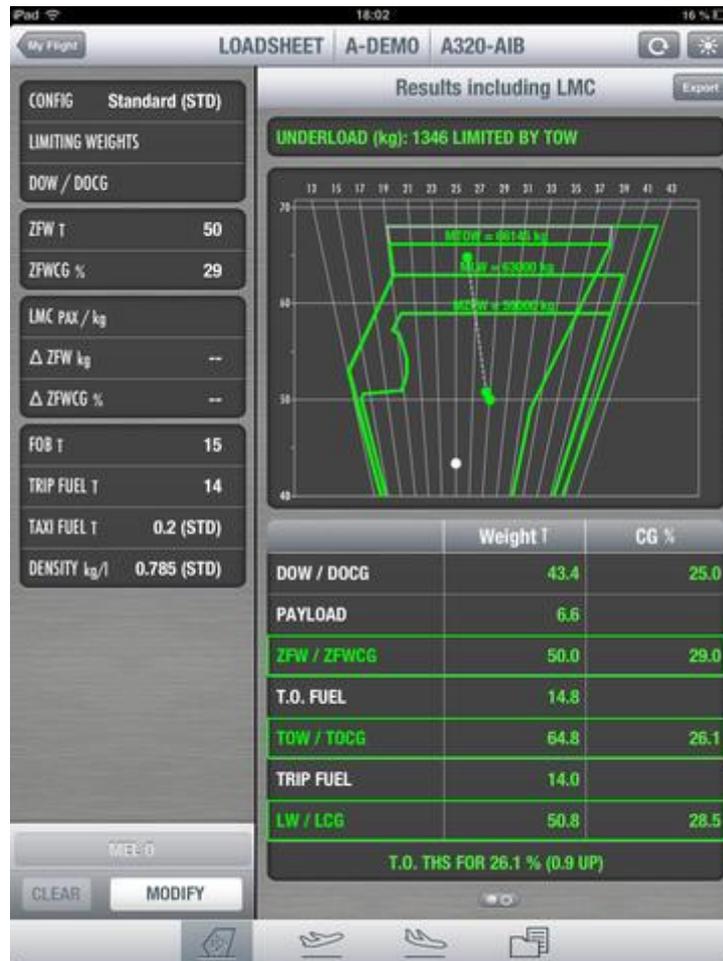


Figure 8: FlySmart Weight and balance calculation (screenshot from Apple iTunes).

8 Financial analysis, model situations and expected drawbacks

In this chapter the costs of EFB implementation for a company will be analysed, the costs of operating without EFB will be compared and the financial and operational benefits of EFBs will be summarized.

The cost of EFB system consists of:

- Hardware price (individual units)
- Software price (various types of licenses)
 - Charts software + updates
 - Other EFB tools as individual applications (performance calculators...)
 - Back office software required (mobile device management tools)
- Mounting devices price + installation costs including required certification (either by external company or by own maintenance workers)
- Human work spent on implementing EFB for the given company (recertification of company operating procedures, communication with companies working on EFB implementation....)
- Human work spent on EFB administration (either dedicated EFB Administrator, or IT department)
- Price of regular maintenance, repairs, and updates/upgrades of hardware and software

The EFB brings following benefits or savings:

- Reduced amount of paperwork for dispatch
 - Lower risk of delays in case of re-dispatch
 - Lower workload for dispatchers compared to printing paper documents
- No need of paper charts and documents
 - Saving of weight of paper charts carried on board of each airplane causes lower fuel consumption. A set of paper charts for one aircraft weights approximately 30 kilograms.
 - Reduced need of manual work frequently updating charts and documents to be carried on board reduces costs of human labour
 -

8.1 Model situation of ABS Jets

ABS Jets is an executive jet operator based at Prague airport. The company used to operate with paper form of documents until 2011. In 2011 an EFB Class III was introduced. The original

Class III EFB was a NavAero Windows XP tablet computer with e-charting application. The STC (Supplementary Type Certificate) to this Class III EFB was issued in cooperation with Aero Vodochody.

In 2014 when service life of the old Class III EFB was approaching its end the decision was made to substitute the old Class III EFB by a new iPad based Class II EFB. During the process of exchanging the old EFB by a new EFB there was no need for additional certification by CAA. Minor Change (MC) of STC was issued by Aero Vodochody – the STC Minor Change and a change in flight manual was only announced to CAA. The STC and MC remain property of Aero Vodochody with ABS Jets being approved to use them under Non-Disclosure Agreement that prevents and details about the installation to be forwarded to 3rd parties.

The STC MC only defines iPad as a hardware platform used for EFB in the whole fleet – no exact models of iPads are stated. The main benefit of this policy is no need for paperwork changes in case of purchasing newer type of iPad for a new aircraft or for replacing other iPad.

Another contributing factor for iPad EFB introduction was a rising need to upgrade laptops used by crew members. This need came at the same time as the need for new EFB. Resulting decision to purchase iPads for EFB meant no need to purchase new laptops.

ABS Jets uses Mobile Device Management by MobileIron. MDM generally means management of mobile devices being done automatically without any action from the end user. IT administrators use MDM to remotely update or install software in the mobile devices (in the case of ABS Jets – iPads) and to manage settings, user rights, and locking (or erasing) the whole device in case of theft.

Except for in-flight purposes, ABS Jets uses their iPads also for other purposes. Using the MobileIron MDM, their users can directly connect to company intranet and use company webs inside the MDM application – there is no need to manually establish VPN connection. The company webs include web forms (evaluation of crew experience with individual handling companies, airports, hotels), duty plans, allowances, and credit card payment overviews. Each ABS Jets airplane has its own BlackBerry device with international internet connection available – this BlackBerry can be used to establish a WiFi hotspot to allow internet access to iPads from anywhere on the ground. Internet signal in flight is not yet available in ABS Jets fleet because of high costs as the only available source of airborne mobile connectivity is satellite phone.

Financial analysis

Following information were kindly provided by ABS Jets IT department. The figures are approximate, but match the real values sufficiently.

Payback period of iPad EFBs was determined to be 3 years. The difference in costs between old EFB Class III and new iPad Class II EFB is the number of devices and licences needed which is now lower than before (Class III EFB had to be installed in every aircraft, now Class II is portable thus being issued for individual pilots that can operate multiple aircraft). The second major saving is caused by Jeppesen e-charting licences being less expensive for iPad EFBs than for Windows EFBs.

Fixed Costs

The cost of transition from Class III EFB to Class II EFB is approximately 400 000 CZK. This includes removal of old EFB, purchase two new iPad EFBs (approximately 18 000 CZK per device), their installation (approximately 230 000 CZK per aircraft) and STC MC when done by Aero Vodochody.

Variable costs

The licence price difference between Windows mobile and iPad Jeppesen subscription is approximately 120 000 CZK per year per device. *For comparison: the annual subscription cost of paper Jeppesen charts varies between 158 000 CZK (charter operator with multiple B737s) up to 437 000 CZK (corporate Legacy 600) and 534 000 CZK (corporate Gulfstream) per aircraft.*

The annual saving per one aircraft is approximately 115 400 CZK when comparing Class III EFB with Class II EFB.

Another variable cost is for MDM subscription – approximately 25 000 CZK per month. This subscription includes licences not only for EFB iPads, but also for other iPads used by the company (line maintenance, flight attendants, IT department...).

Research usage of iPads

ABS Jets is the only Czech airline that cooperates by testing at project “Advanced Meteorological Information for Aviation” by TA ČR. In this project, Honeywell International is researching technology of delivering and displaying real-time world-wide meteorological information on iPads during flight (radar images, CB forecast and cloud tops, CAT, wind data, SIGMET, METAR, TAF, ATIS and icing data).

According to Honeywell,

(...) the function of the Weather Information Service is to assist the flight crew in making strategic, in-flight decisions with respect to weather information by providing up-to-date weather data (e.g. along route, areas of interest, etc.). Additionally, the Weather Information Service can provide optimization of the flight path due to the availability of the most recent weather information (12).

This Service utilizes an Electronic Flight Bag (EFB) datalink application that assists the flight crew in decision making related to route safety and optimization. The system uses real-time weather and trend information from the cockpit, as well as enhanced communication including current weather, historical weather patterns, and weather forecast to give the flight crew the clearest view of weather (12).

Figure 9 shows example of the application under development.

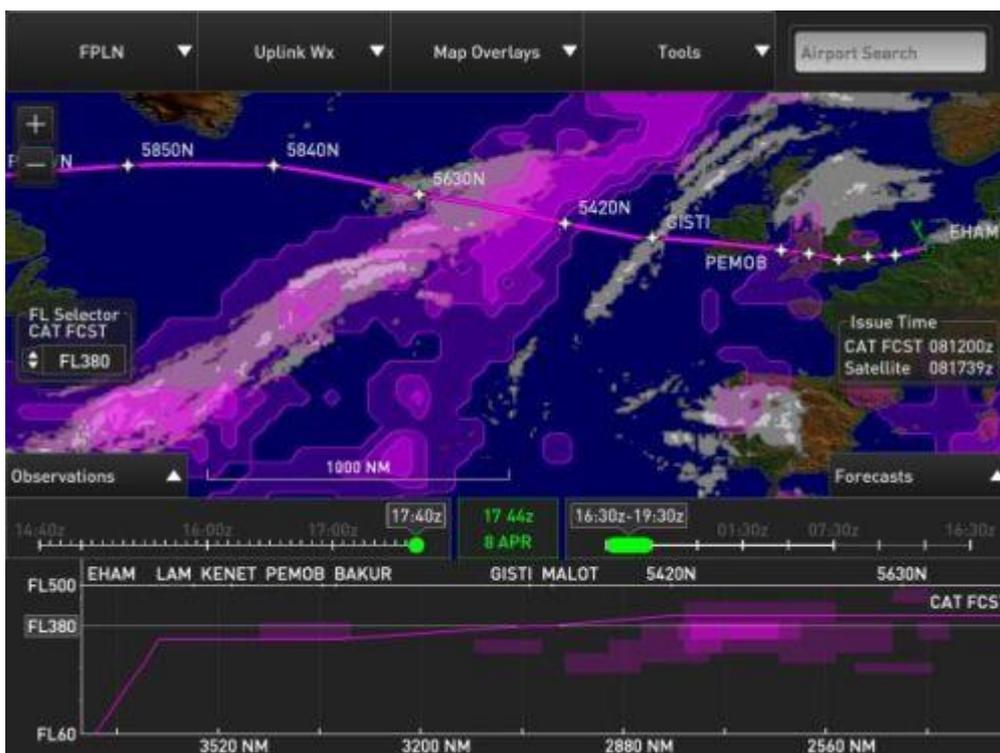


Figure 9: Honeywell Weather Information Service example (image from honeywell.com)

8.2 Model situation of Travel Service

Travel Service switched to using EFBs in March 2015. Prior to the official transitions the company had been undertaking a six months testing period when the EFBs were carried on board simultaneously with paper charts. This testing period was a requirement of CAA.

As per July 2015, Travel Service currently employs ca. 400 pilots. Every pilot was given his own iPad for EFB usage. This solution also means no need to provide crews with their own laptops.

Even after EFB introduction, paper enroute charts remained on board of all aircraft. This step provides sufficient redundancy for case of EFB failure and allows CAA approved operations with single EFB inoperative.

Boeing aircraft were equipped with Fokker Services mounting devices for iPads. Airbus fleet was already equipped with custom mounting devices after being received from Czech Airlines. Cessna fleet (business jets) is currently in the process of EFB planning and preparation and will probably be equipped with Class I EFBs that don't need any mounting devices and CAA approval.

8.2.1 Boeing fleet

Boeing pilots at Travel Service use iPad AIR (A1475) for EFB (4). Their applications are Boeing Jeppesen FliteDeck Pro and Boeing OPT. The FliteDeck application is used for electronic charting, and the Boeing OPT is a tool for performance calculation. There is currently no weight and balance application implemented, but it is planned for future extension. Together with those two applications, Adobe Reader is used for displaying PDF documents. This set of three applications is locked and cannot be modified or removed by pilots. Together this package is certified by CAA. For certification, the Jeppesen FliteDeck Pro and Boeing OPT are considered Class B applications, while the Adobe Reader has no classification, but is approved for static documents viewing (13).

Updating of obstacle data in Boeing OPT is done on daily basis. Navtech company provides Travel Service with update file that is uploaded by TVS EFB administrator to <https://www.myboeingfleet.com> website under TVS company profile. Crew can download the update using the Boeing OPT application whenever the iPad is connected to WiFi network with internet access. The update is available approximately 2 hours after being uploaded by EFB administrator.

Jeppesen FliteDeck Pro charts and route manuals are updated by the Jeppesen company every week. Company manuals (like airplane documentation, SOPs, etc.) can be updated using Jeppesen Distribution Manager website (JDM). After PDF documents are uploaded to the JDM, they are downloaded by Jeppesen FliteDeck application together with next Jeppesen charts update. The result of this updating policy is that crew gets the updated company manuals not before next Jeppesen update – which can in worst case be 2 weeks after being uploaded to JDM by EFB administrator.

The solution of the slow updating interval of company manuals for Jeppesen FliteDeck could be installing another 3rd party software capable of synchronization of PDF documents between company server and user iPad in real time and certification of this application by CAA.

8.2.2 Airbus fleet

iPad 3 (A1430) is the hardware platform for EFB in Airbus fleet at Travel Service. The software consists of Airbus LPC NG suite which features applications: Loadsheet, Landing, Take-off, OLB and Manager. Loadsheet, Landing and Take-off are applications used for performance calculations according to their names. OLB is a PDF and XML document viewer used for viewing company documents (SOPs, FCOMs...) in the EFB. Manager is an utility used for updating all the LPC NG applications whenever the device is connected to the internet. The Airbus fleet also uses Jeppesen FliteDeck Pro, which is the only application common for Boeing and Airbus EFBs (13).

The updates of Jeppesen FliteDeck Pro are done in the same way like in the Boeing EFBs – using the integrated updating tool in the application. The LPC NG Manager is capable of downloading updates for all the Airbus applications. Company documents are updated by the EFB Administrator by uploading them to FlySmart Gateway intranet website (which runs on the Travel Service own server). The LPC NG Manager then downloads these documents together with other updates (e.g. obstacle data) from other sources and uses them instantly in the OLB application.

9 Conclusion

In this thesis an overview of EFB Class II implementation was done. Following text can be considered as a recommendation for a hypothetical airline which is considering switching to EFB usage, especially Class II. Differences between the two studied companies and the hypothetical airline must be taken in consideration – factors like size of the company, aircraft types in fleet, type of flights operated, training of flight crews, current on-board equipment of aircraft and technological aspects of IT department may play key role in the decision about iPad EFB suitability.

9.1 Fuel efficiency point of view

According to Travel Service, the EFB can be beneficial in weight difference between flying with paper documents and flying with only two iPads on board. Following calculation will try to approximate the dependence between payback period of EFB and flight hours operated with Boeing 737-800. Due to company secrets of both Travel Service and ABS Jets of the company, the values are only approximate.

9.1.1 EFB costs

Fixed costs (EFBFC)

Two iPads	36 000 CZK
Jeppview Fitedeck	0 CZK
EFB installation and certification	300 000 CZK

Variable costs (EFBVC)

Jeppview e-charts subscription	195 000 CZK per year (16 250 per month)
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9.1.2 Non-EFB operations costs

Fixed costs

0 CZK

Variable costs

Jeppesen paper charts subscription 182 000 CZK per year (15 166 per month)

9.1.3 EFB savings

(to be added to Non-EFB operations variable costs)

Fuel consumption

Weight saving with EFB 30 kg per flight (according to TVS EFB Admin.)

Fuel saving per 30 kg of operating wt. 1,46 kg⁴

Fuel price (JET-A) in July 2015 (IATA) 540,7 USD per 1000 kg = 13,31 CZK per 1 kg

Total saving per typical flight with EFB 1,46 × 13,31 = 19,43 CZK

1000 NM flight time 2:24 hours

Total saving per 1 hour of flight with EFB 8,1 CZK per 1 hour of flight time

Typical flight time per year 3 250 hours⁵

⁴ Data were interpolated from Boeing 737 FCOM vol. 1, 737-800/CFM56-7B26 Performance Dispatch – Enroute, chapter PD.31.4. (14)

Trip Fuel and Time Required

AIR DIST (NM)	TRIP FUEL (1000 KG)							TIME (HRS:MIN)
	LANDING WEIGHT (1000 KG)							
	40	45	50	55	60	65	70	
1000	4.5	4.8	5.2	5.6	5.9	6.4	6.7	2:24
1400	6.2	6.5	7.1	7.7	8.2	8.8	9.2	3:17
1800	7.8	8.3	9.1	9.8	10.5	11.2	11.9	4:10
2200	9.5	10.2	11.1	12.0	12.8	13.7	14.6	5:03
2600	11.3	12.1	13.2	14.2	15.3	16.3	17.4	5:56
3000	13.0	14.1	15.3	16.6	17.8	19.0	20.2	6:49
3400	14.9	16.1	17.5	19.0	20.3	21.8	23.2	7:42
3800	16.8	18.2	19.8	21.4	23.0	24.6	26.2	8:34
4200	18.8	20.4	22.2	24.0	25.7	27.6		9:27
4600	20.8	22.6	24.6	26.6	28.6	30.6		10:20
5000	22.9	24.9	27.0	29.3	31.5	33.7		11:13

**Based on 280/.78 climb, Long Range Cruise or .78 and .78/280/250 descent.
Valid for all pressure altitudes with 4000 ft step climb to 2000 ft above optimum altitude.**

1000 NM flight (can be considered routine for B737 operations), difference in landing weight of 30 kg means 1,46 kg difference in fuel required. This is a result of least squares analysis method. Calculation is attached to this thesis.

⁵ Number was calculated as an average from flight times of Boeings 737 at year 2014 (Travel Service)

Total saving on fuel per year with EFB 26 325 CZK

Total saving on fuel per month with EFB 2 194 CZK

9.1.4 Payback period calculation

$$EFBTC(t) = EFBFC + EFBVC \cdot t \quad (\text{Equation 1})$$

Where EFBTC = EFB Total Costs at given month

EFBTC = EFB Fixed Costs

EFBVC = EFB Variable Costs

t = time (months)

$$NONEFBTC(t) = NONEFBVC \cdot t \quad (\text{Equation 2})$$

Where NONEFBTC = Non-EFB operations Total Costs at given month

NONEFBVC = Non-EFB operations Variable Costs

t = time (months)

Payback period is the point, where EFBTC and NONEFBTC equal:

$$EFBFC + EFBVC \cdot t = NONEFBVC \cdot t \quad (\text{Equation 3})$$

After algebraic expression of t:

$$t = \frac{EFBFC}{(NONEFBVC - EFBVC)} \quad (\text{Equation 4})$$

$$t = \frac{336\,000}{(15\,166 + 2\,194 - 16\,250)} \cong 303 \text{ months} \quad (\text{Equation 5})$$

Following Figure 10 shows dependence of EFB total costs and non-EFB variable costs on time since EFB introduction. The third line shows non-EFB variable costs without considering the fuel factor. The point where EFB TC line and non-EFB VC + fuel line cross is the payback period – time after which the EFB is actually saving money. As shown in the chart, the roughly estimated payback period for our case is 303 months. The fuel saved by EFB operations is included in non-EFB costs, because we need to compare costs of EFB and cost of non-EFB operations together.

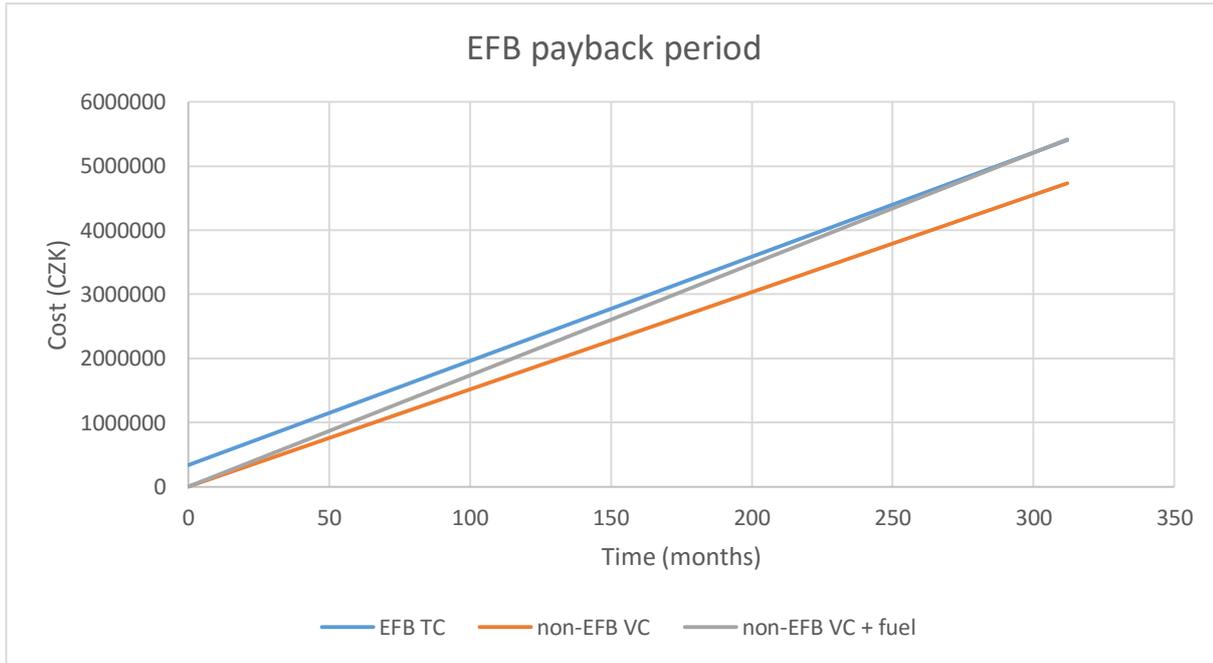


Figure 10: EFB payback period (graphical representation)

The result of 303 months payback period is way higher than the statement of Travel Service who estimates the EFBs to pay back in few years. The result of this huge error can be caused by Travel Service including some (to us unknown) operational benefits into the savings, or misleading costs provided for purpose of this thesis.

9.2 Point of view comparing EFB Class III costs

The previous calculation is more suitable for an airline with high number of flight hours per year. However even other airlines may find EFB Class II financially beneficial, even if the saved fuel is negligibly small. As reported by ABS Jets, the price difference between EFB Class III and EFB Class II is approximately 120 000 CZK per year, which would effectively payback the 336 000 installation investment in less than 3 years.

9.3 Operational point of view

Apart from the financial savings when compared with EFB Class III operations or in case of positive savings compared with non-EFB operations, the EFB can bring certain operational benefits to the airline. Having the EFB implemented means easier, faster and cheaper process of updating paper documents on boards (company manuals, aircraft documents, navigational charts...). For OCC the EFB means faster and easier delivery of OFP or its changes in case of re-dispatch. The physical EFB Class II device (which is portable and is usually issued to individual crew members) means also no need to purchase a personal laptop. The crewmembers can use EFB to access company intranet, monitor their duty plans, fill reports, or just to access e-mail and internet browsing. The iPads are also capable of installing various applications that do not directly fall under EFB regulations, but can be used for aviation generally – like weather applications, hotel booking tools or generic calculators. Company that has implemented iPads or tablets generally can use this platform even for other employees – for example maintenance paperwork, or team communication.

I believe that the summary provided in this thesis could be practically usable for an airline that is currently deciding about EFB implementation. However lot of significant Czech companies have already switched to EFB (Czech Airlines, Travel Service, ABS Jets...), there is currently still lot of operators in (e.g. aero taxi companies, corporate jets operators...) who operate with paper documents in the cockpit. EFBs can provide a robust, modern and user friendly solution that can contribute to operational efficiency, reduce operational costs and enhance crew working environment even outside of the flight deck.

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11 Attachment 1 – calculation of dependence between trip fuel and landing weight

Tool used: least squares calculator (MS Excel file) by Department of Applied Mathematics (K611).

	Význam	Jednotka
Proměnná X:	Landing weight	1 000 kg
Proměnná Y:	Trip fuel	1 000 kg

Závislost je přímka, která neprochází počátkem: $Y = a.X + b$

č.	xi	yi	yi p
1	40,00	4,50	4,46
2	45,00	4,80	4,84
3	50,00	5,20	5,21
4	55,00	5,60	5,59
5	60,00	5,90	5,96
6	65,00	6,40	6,34
7	70,00	6,70	6,71
8			1,46
9			1,46
10			1,46
11			1,46
12			1,46
13			1,46
14			1,46
15			1,46
16			1,46
17			1,46
18			1,46
19			1,46
20			1,46

reziduální součet čtverců

So 0,01

odhad směrodatných chyb

s 0,0471

sa 0,001778557

sb 0,0994

regresní koeficienty	
a	0,0750000
b	1,4607

n	7
Suma xi	385,000
Suma yi	39,100
Suma xi*yi	2 203,000
Suma xi^2	21 875,000
Suma yi^2	222,350

