The past decade has seen advancement in technology to assist maintenance and flight operations staff in supporting aircraft operations. The flightdeck has seen a similar revolution. Electronic flight bag (EFB) and electronic technical log (ETL) solutions are examined.

New solutions for electronic flight bags & electronic technical logs

The last decade has seen growth and advancement in technology on the ground to assist maintenance and flight operations staff in becoming more efficient and effective at supporting daily operations. Over the past few years the cockpit has seen a similar revolution, bringing new technology for pilots and mechanics alike to transform business processes. The electronic flight bag (EFB) and electronic technical log (ETL) solutions are examined.

Computers in the cockpit

For decades pilots carried large flight bags whenever they boarded an aircraft. These were stuffed with paper, sometimes weighing 15-20kg, and included: checklists; landing approach plates; visual flight rules (VFR) charts; trip books; flight operations manuals (FOMs); company manuals; performance tables; and various other handbooks. Many pilots still carry a bag, but these days it is more likely to contain items such as sunglasses, medicine, a first-aid kit, headsets and spare radios.

The paper has been mainly replaced by computer devices, which are either carried onto the aircraft or already integrated in the aircraft's flightdeck. These EFBs perform increasingly complex and wide-ranging functions, from real-time re-calculation of take-off and landing performance to electronic form-filling that can be linked directly from the aircraft to ground-based systems. This might include fuel uplift information or technical logbook functions.

Computers began appearing on the flightdeck two decades ago when pilots started taking personal laptops on the aircraft. They used standard software packages like spreadsheets and word processing to complete forms and perform calculations. It was a simple step towards creating the first airline-specific applications, and the initial focus was on take-off performance calculations.

As early as the mid-1990s, Spirent Systems (later part of Teledyne Controls) developed a number of solutions for Southwest and FedEx to improve flightdeck efficiency, and began to remove paper from the cockpit. Southwest pioneered a paperless take-off performance system called on-board performance system (OPS). This ran on a standard ruggedised touch-screen tablet computer. FedEx likewise deployed some cockpit applications on commercial off-the-shelf (COTS) laptops, which included an on-board maintenance terminal (OMT). This could be used to log maintenance faults, and was connected to the central maintenance computer (CMC) on its MD-11 and Airbus fleets to read the fault messages from the CMC and provide more detailed information to assist troubleshooting. Also hosted on these laptops were a number of document browsing capabilities for the aircraft maintenance manual (AMM), illustrated parts catalogue (IPC), minimum equipment lists (MELs) and operating manuals for the line mechanic to access at the gate for use during line maintenance. Others followed Teledyne's lead and a number of solutions appeared on the market. OEMs followed. These solutions in the cockpit became known as EFBs.

Types of EFBs

All EFBs now follow guidance set out in the Federal Aviation Administration (FAA) Advisory Circular 120-76A, and in the Joint Aviation Authorities (JAA)/ European Aviation Safety Agency (EASA) temporary guidance leaflet TGL36, 'Guidelines for the Certification, Airworthiness, and Operational Approval of Electronic Flight Bag Computing Devices'. According to these documents, an EFB is an electronic display system intended primarily for flightdeck or cabin use, to enable cockpit or flightcrew to carry out various tasks aided by computer-based calculations and access to electronic documentation.

There are two main categories of EFBs: standalone systems which are generally portable laptops; and fixed systems installed into the aircraft as part of the on-board avionics systems. The FAA and EASA documents on EFBs, however, classify these devices into three categories: standalone portable; cockpit-mounted; and fully integrated. These will be addressed below.

Class 1: Standalone portable

Class 1 is a COTS-based computer or handheld portable data assistant (PDA). The device is fully portable, and runs basic standalone software applications.

Either device is generally used on the ground or during non-critical flight phases to access information traditionally held in paper form. It acts as an enhancement to the primary data sources, and not as a replacement. They are also used to carry out form-filling activities, and in ground-mode they can connect and link data off-board to ground-based systems. Generally Class 1 EFBs are powered by the aircraft and can be stowed in docking stations. These stations will need supplemental type certification (STC). Class1 EFBs require the minimum investment in hardware and systems integration.

The 777 can be retrofitted with a Class 3 electronic flightbag. KLM was the launch customer in 2002.

Class 2: Cockpit-mounted

Class 2 devices are generally COTS-based systems, which are portable, connected to the aircraft during normal operations, and require an administrative control process for approval. They can also be purpose-built equipment and are designed to be available and visible during all flight phases. Class 2 equipment can be used for viewing previously paper-based information such as navigation charts and approach plates. By their nature they will require more expensive hardware than Class 1 as well as more administrative costs to ensure approval as they replace paper-based critical information. They require redundancy for safety and are generally integrated into cockpit systems, while remaining removable.

Class 3: Fully integrated

Class 3 devices are fully installed equipment. For the Class 3 EFB, installation of the display units, aircraft system interface units, and associated wiring is certified through an amended type certification, including compliance with RTCA/DO-178B functional hazard assessment.

The main difference between Class 2 and 3 devices is that the latter are fully integrated into the aircraft cockpit displays, rather than being portable and removable. The new generation of aircraft, such as the 787 or A380, have Class 3 EFBs built into their flightdecks. They generally provide aircraft, engine and other system health data and provide a broader spectrum of interactive applications for navigation and performance management. The hardware is also subject to a number of RTCA DO-160E requirements related to safety and radiated emissions testing.

EFB software types

There are also three types of software that can be used by any EFB, which are determined by the function and applications that each device can run.

Type A applications use pre-composed and fixed data, in formats such as PDF, HTML or XML, and are generally used for reference manuals and electronic forms that can be filled in on the computer.

Type B software uses dynamic and interactive data and needs additional approvals. It also includes non-interactive electronic approach charts. It may have video camera display and real-time weather maps.

Type C applications are complex and flight-critical. They may be part of an automatic dependent surveillance-broadcast system, for example. Type C applications must be operated on Class 3 EFBs, so they are also subject to additional RTCA/DO-178B airworthiness requirements for airborne software. There can be a multitude of combinations of hardware and software that fall under the EFB tag.

Regulating the computers

The hardware and software used to run an EFB are tightly regulated in AC 120-76A and EASA TGL36. The guidelines allow pilots to replace traditional paper manuals with the EFBs and also provide direction on where to position the EFB in the cockpit to avoid interference with other systems. These guidelines also indicate what should be done in the event of data loss.

The permission to use the EFB will depend upon what type of aircraft is being used and for what purpose. For air carriers with Part 135/121 and holding operating certificates, they must seek individual approval from the local flight standards district office or local EASA office. This must be done for each aircraft and for each operation.

For Part 91 operators which are not flying for hire, which includes corporate operators, they can use pilot-in-command authority to approve Class 1 and 2 portable devices.

General aviation aircraft operating under Part 91 do not require authorisation or design approval, provided the EFB does not replace any system or paper.

These regulations have meant that business jet operators have led the way in development and use of EFBs. The Bombardier Global Express range has Goodrich equipment fitted. The PilotView EFB from CMC is optional equipment on the Embraer Legacy 600 and Lineage 1000. All Gulfstream G550s are fitted with CMC's Class 2 EFBs fitted to the control yoke on the pilot's side. The trend in business jets is to incorporate the EFB into the primary front displays.

Challenges for new technology

The tight regulations have imposed some unwanted restrictions on the use of EFBs, particularly with Class 3 devices. Since they need to be integrated into the aircraft they cannot be removed and placed in docking stations for use outside the aircraft. This imposes some limitations on their use by pilots for ground activities.

Another issue concerns the lack of standardisation of EFBs. Each manufacturer and software vendor has a unique view of the user interface including screen layout, navigation and data entry method. Some use touchscreens, others keyboards or navigation buttons. There is also a plethora of different screen sizes and aspect ratios. This all leads to concerns about user-friendliness, especially in flight and during periods of heavy pilot workload.

A third concern voiced by some airlines and aviation groups is the potential lack of choice if the aircraft manufacturers impose a single preference. Boeing acquired Jeppesen in October 2000 and entered the EFB market by offering a full range of EFB options, from Class 1 through to fully integrated Class 3 on the 777 and new 787. An EFB is

	Asia Flag Carrier	Euro Charter	Asia Low Cost	Asia Flag Carrier	Euro Low Cost	US Regional	Asia Major Carrier	Euro Flag Carrier	Asia Regional
Pre-flight Line Maintenance									
Departure Check	X			X	X	X	X	X	X
Fueling	X	X		X	X	X	X	X	X
Load Sheet	X	X		X	X		X	X	X
Data Distribution (for Flight Operations)									
Update Airport Analysis (NOTAMS)	X	X	X		X			X	X
Update Internal manuals	X		X					X	X
Update OEM procedures	X		X					X	X
Update Navigation data (paper)	X		X					X	
Update Navigation data (CD)			X						X
FMS Data			X						X
Distribution to aircraft	X	X	X		X			X	X
Distribution to crew	X		X					X	X
Flight Operations									
Scheduling			X			X			
Rostering			X			X			
Planning	X		X	X		X		X	X
Check-in	X		X	X		X	X	X	X
Pre-flight/dispatch	X	X	X	X	X	X	X	X	X
Fly/post-flight	X	X	X	X	X	X	X	X	X
Reporting/Tracking	X	X	X	X	X	X	X	X	X
Cabin Crew Operations									
Check-in/briefing	X		X				X		X
Pre-flight/dispatch	X		X				X		X
Fly/post-flight	X		X				X		X
Reporting/Tracking	X		X				X		X
Post-flight Line Maintenance									
Discrepancy resolution	X	X		X	X			X	X
Defect deferral	X	X		X	X			X	X
Reporting/Tracking	X	X		X	X		X	X	X
Fuel									
Data collection	X	X	X	X	X			X	X
Monitoring use vs. plan								X	
Reconciling fuel records	X	X	X	X	X				X
Processing payments	X	X		X					X
Training									
Type certification								X	
Recurrent								X	

AMT has been running a series of process workshops with a wide range of airlines around the world. Each type of airline has a different range of processes to manage and so the EFB solution needs to be flexible.

expected to be offered on the 737 and 747s as a Class 3 solution.

The Jeppesen EFB offers all the functionality of other EFBs, and Boeing is already selling it to 777 customers. It is a standard feature of the 787's new cockpit. Boeing is partnered with Astronautics for the EFB for the Class 3 displays in the 777 and 787. Functionality includes airport moving maps for taxi position awareness (TPA) and graphical weather displays en-route. The EFB also integrates the cabin video surveillance for increased security. This potential lack of choice would be overcome if a standard plug-and-play interface and installation were available.

In reality, the issue of standardisation is only likely to be clarified as competition shakes out the winners and losers, and the more powerful large airline groupings exert their influence. Competition and choice are most likely to be strongest for the software applications.

Where is the money?

EFBs promise a system that can allow an airline's personnel and aircraft to be seamlessly connected to the company's business systems. This can yield dramatic cost savings as well as major improvements in the performance of the airline's business processes.

One company that has been forging a path for the EFB for several years is Aircraft Management Technologies (AMT). AMT has recently conducted a series of workshops with several airlines to analyse and quantify the value proposition surrounding connected technologies and information management in the context of aircraft operations. The technologies considered included: EFB types of applications; the use of laptop or tablet PCs either as COTS hardware, or as installed aircraft equipment by flightcrew and ground users; integration to existing airline back office systems; and airplane-ground connectivity of the entire system. To grasp the process changes that are possible by using such technologies it is important that an airline understands its current process and can map and target improvements to be overlaid on its current operation. There are a range of benefits that airlines can target through the implementation of such technologies.

Six major processes were examined by AMT in workshops with nine commercial airlines. The processes were: maintenance pre-flight; data distribution for flight operations; actual flight operations; cabin crew operations; maintenance post-flight; and fuel reconciliation and payment. These existing processes were mapped in detail by teams consisting of airline personnel that were familiar with the actual operation of the current process. The work of these teams was facilitated by AMT consultants, but the actual output of the workshop was the result of efforts by team members from each of the participating airlines. Following the mapping of the existing or 'As Is' processes, the teams then examined ways in which the processes could be improved by the application of modern information technology. These new 'To Be' processes were also mapped in detail.

This process analysis methodology was developed by AMT through a series of similar workshops at other airlines. During and after the workshops, AMT modelled and analysed the airlines' processes using a software package called Websphere Business Integration (WBI) Workbench, which is a tool that can graphically represent a business process and quantify its performance. The results of this work were then reviewed in detail during follow-on visits with key personnel at each of the airlines.

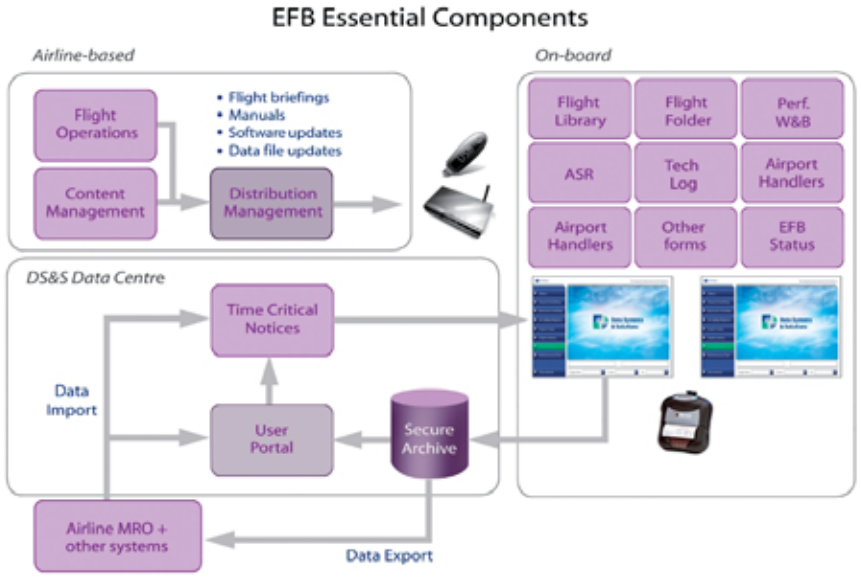
In summary, the nine airlines analysed believe there are significant savings to be achieved through the use of EFBs and ETLs in the six process areas analysed. The cost reduction was estimated to average almost $300 per flight. At average utilisation rates this would equate to more than $300,000 per aircraft per year. Process times were estimated to improve, with the elapsed process time reducing by 80% and the working time in the examined processes reducing by 60%. This would result in improved dispatch reliability and on-time performance, increased customer satisfaction, and enhanced crew morale and employee motivation.

The types of changes that deliver these benefits include reducing reliance on ground-based manual processes in dispatching the aircraft, eliminating load-sheet bottlenecks by calculating weight and balance on aircraft, a reduction in crews' duty time, together with pilots' and flight attendants' check-in and brief on board the aircraft.

Fuel and maintenance are two other big opportunity areas. Reconciliation and management of fuel purchasing is facilitated with real-time electronic records from both crew and fuel operator. Real-time technical log and maintenance management means reliability reports are generated in minutes instead of weeks. Simple things like documentation management improve with the knock-on benefit of the elimination of cost in distributing Navigation Data and Manuals.

These are gross savings, and do not take into account the cost and time of implementing a total solution, which involves not just aircraft hardware and software, but also ground infrastructure, systems integration, connectivity, and, perhaps most importantly, significant organisational change.

"We take a holistic view of the EFB solution," says Aidan Gallagher, chairman at AMT. "It should be viewed really as a framework, rather than as a computer running applications. We talk about an aircraft as an 'occasional connected asset' in an airline



The essential components of an EFB system include the ability to electronically sign the technical logbook. Airlines need to think carefully about all the elements of the ground and air infrastructure.

organisation. Sometimes it has good, high bandwidth connectivity generally when it is on the ground. In the air it may have narrow connectivity through more expensive satcom or ACARS. Or it may fly with no connection to the ground back office. The ground infrastructure is the starting point, rather than any one application. That is one thing that makes AMT's approach unique. Our solution can start as an ETL or as a solution for viewing maps. We can plug and play our Flightman solution with anyone else's. For example, we sell Flightman through a partnership with Rockwell Collins. We have pilot implementations at First Choice, bmi, Neos and SIA. The regulatory framework for the EFB is a crucial enabler or disabler and needs careful attention by the airline management."

The electronic signature

One of the challenges that EFB providers have to overcome is the delicate issue of electronic signatures. Many applications are replacing paper-based processes that require a signature for legal reasons. The requirements for the use of electronic signatures are set out in the FAA AC 120-78. "The Flightman product requires all users to log in to the system prior to using the application," says Joe McGoldrick, chief technology officer at AMT. "The process involves the user identifying themselves to the system by username. The Flightman client then needs the user to provide an authentification code by either entering a password or using a token-based mechanism, such as a USB Key or swipe card. In our deployments so far, each username has an associated password code. The authentication of the user is achieved by generating a code on the EFB of the entered password and comparing it against that of the password in the system. The advantage of using the code is that at no time is the clear text password stored in the EFB system. The user names and associated password codes are imported from the backend crew/user management system on a periodic basis and any changes are propagated to the EFBs.

"The EFB log in process ensures that each user capable of signing an electronic document is uniquely identified by the system," continues McGoldrick. "Once authenticated, the user is assigned access privileges to particular elements of the application. The process of electronically signing a record prompts the user to review the inputted data prior to sign-off. Those sections of the documents being signed off are indicated through the deployment of a colour coding scheme. A user is not allowed to sign off a record until all mandatory fields have been entered. The significance of signing the record is indicated to the user by enforcing the physical signing of the document, either by using the device's stylus or by re-entering their password. The user is then prompted to confirm that the correct data are present in the record prior to the signature being attached. The signature itself consists of the user's name together with, where appropriate, the inputted stylus signature. The user's name is populated by the application based on the identification code entered by the user during the log-on process, and cannot be changed by the signer. This has been locally approved for our current customers and is the way forward at present with the regulator."

Lufthansa provide content

"Focusing on paperless flying is not sufficient when converting an airline's existing flight operation processes into integrated digital processes," says Marc Szepan, senior vice president of airline operations solutions at Lufthansa Systems. "Only an integrated overall concept that brings pre-flight, in-flight and post-flight as well as on-board and ground services together, can exploit the full potential. This is achieved by Lido eFlightBag, an EFB solution that provides cockpit crews with an electronic information management system throughout the entire flight process."

Lido eFlightBag optimises information processes on the flightdeck and meets the strict requirements for information quality and processing speed. It integrates a variety of applications for paperless planning and the execution of flights. The individual modules use a shared database and exchange information amongst them. This guarantees that uniform information is available throughout the entire flight. Lido eFlightBag also enables on-line access to current operational data and other important flight-related documents.

"The EFB solution from Lufthansa Systems can be used regardless of the hardware or aircraft model," claims Szepan. "It can run as a Class 1 solution on notebooks, or it can be permanently installed in the cockpit as a Class 2 solution, or integrated with a Class 3 on-board information solution. Examples of the applications in our Lido eFlightBag include: 1) Electronic Flight Folder, which bundles all flight-related data and documents in a standardised structure; 2) the Library Document Viewer, which facilitates the electronic display of general operations manuals and all other flight-specific documents; 3) Lido eRouteManual, which provides electronic navigation charts from Lufthansa Systems to enable pilots to see all relevant flight information at a glance; 4) Lido Take-off Performance Analysis (TOPAS), which calculates the optimal take-off data while taking all relevant factors into account, including obstacle data; and 5) Electronic Flight Operations Manual (EFOM) a powerful tool for managing, authoring and publishing structured XML data.

"The future EFB-solution of Lufthansa is based on Lido eFlightBag," continues Szepan. "An EFB-solution ensures the availability of the latest information and operational data. Printing and distribution costs are

MyTravel was the first airline in the world with a totally paperless technical logbook operation using the DS&S Class 1 solution.

avoided. Lufthansa saves up to 16 million sheets of paper by switching to a full 'paperless cockpit'."

This is backed up by customers. "The current version of the Pilot's Workpad has made Lufthansa a pioneer in the introduction of the paperless cockpit," says Jürgen Raps, executive vice president operations at Lufthansa. "Even now, Lufthansa, our crews and our passengers benefit in various ways each day from the tremendous economic and operational advantages of this technology."

The future is today

There is a clear trend today: Class 2 devices are becoming the most sought-after of the three types. There are good reasons for that. The ownership costs for the fully integrated Class 3 devices are extremely high, because they are treated as part of the avionics equipment and are therefore subject to the high certification standards that are compulsory for avionics systems in the cockpit. Moreover, the flexibility of Class 2 devices is significantly greater. For example, it is possible to upgrade hardware components without going through further steps of certification. An EFB solution improves the level of communication between the flightdeck and the MRO department. An EFB as an integration platform for applications such as e-tech logs will be instrumental in optimising maintenance processes. It will also help reduce aircraft ground times by transmitting detailed real-time information regarding discrepancies on-board while still in flight.

Technically speaking

Views differ on where value begins for computers in the cockpit. "We at DS&S are leaders in state-of-the-art ETLs and EFBs," claims Nick Godwin, marketing director at DS&S. "There is no doubt that the ETL has proven itself as the highest-value application in operation today. Some airlines start by looking at EFBs for operations, but the big value-added areas are maintenance, fuel management and other technical related areas. Many airlines started with the ETL, but it is important to stress that each success story has been a journey. There are many steps to the journey and decisions to be made at junctions and cross roads. There have been some high profile EFB implementations in Europe and Asia that came to nothing. We still have the first fully paperless ETL approved by the regulator anywhere in the world with My Travel. Indeed, it is ready for full integration with its ground MRO software system. As a result of the Thomas Cook merger, a second rollout is now under way with them."

The big challenge for EFBs and ETLs has been integration across departments. Why has it taken so long for the mainstream airlines to embrace the technology? The answer is partly in the integration challenge, but also that while early innovators are willing to take a chance, others are sitting back waiting for mistakes to be ironed out and the technology and process re-designs to mature. "We are now on the crest of the early adoption wave," predicts Godwin at DS&S. "If we had started with Class 2 then we all would have failed. The simple Class 1 device is the way to start. The crucial bit is to understand the airline's processes; you will not be able to impose new processes on an airline so your solution needs to be flexible and adaptable. One of our unique selling points is literally the fact that we have successfully accomplished an implementation and now can take that model and replicate it at other airlines. Most other vendors have failed to achieve this track record.

"We are finding Europe is fertile ground for the ETL and EFB. The USA is quite political and unionised and there needs to be a strong change management exercise accomplished alongside the technology. We are finding the big improvement areas are in dispatch reliability, fixing problems rather than simply finding them, fuel management and crew management. In fuel alone, airlines can save 1-2% on their fuel costs by optimum tankering, identification of rogue aircraft, accurate centre of gravity calculation and simple invoice reconciliation through more accurate data capture.

"Regulator approval is also a challenge. The airline still has to operate under the EASA temporary guidance leaflet and this is slowing things down. Each operator needs to seek and obtain local approval. There tends to be a dovetailed paper-on/paper-off exercise before the regulator allows operation, and this extends the implementation timescale. EASA is looking to MyTravel as an industry pathfinder, so perhaps changes are coming from the regulator. There is also a challenge in commonising system language standards."

The future

There is no doubt that technology can still continue to advance us towards a day when the aircraft really is just another 'node' on the Wide Area Network (WAN) of an airline. "But the future is not just about the cockpit," claims Gallagher at AMT. "In-Flight Entertainment (IFE) is everywhere and needs synchronisation. In-flight phones and mobiles are increasing in use, and shopping in flight is becoming popular. All this needs a ground infrastructure. Management of on-board content, both in the front and down the back of aircraft, is the real future". But just like Connexxion from Boeing, only time will tell. AC