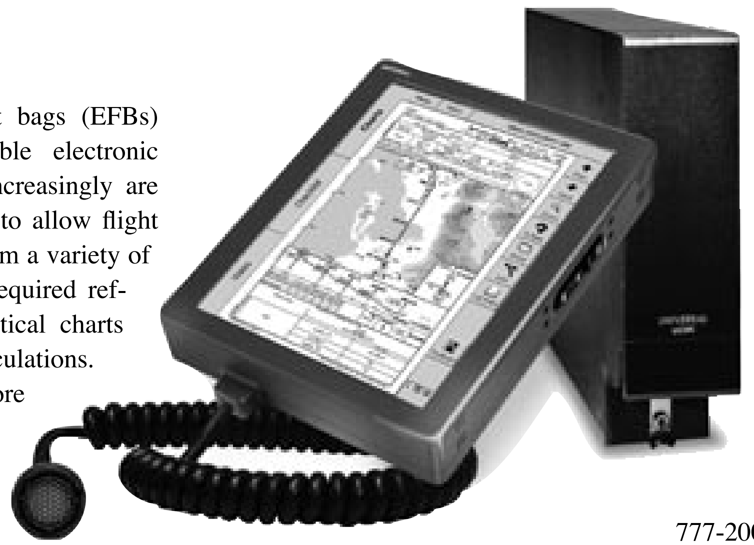
‘Paperless Cockpit’
Promises Advances in Safety, Efficiency

BY FLIGHT SAFETY FOUNDATION EDITORIAL STAFF

Electronic flight bags are eliminating considerable paper from the flight deck while offering the flight crew a wide array of technological assistance. Nevertheless, these still-changing tools require more than casual understanding before flight crews can replace paper with electronics.



Electronic flight bags (EFBs) are customizable electronic devices that increasingly are in use on flight decks to allow flight crewmembers to perform a variety of tasks that previously required reference books, aeronautical charts and mathematical calculations. Some EFBs are no more than off-the-shelf portable computers with flight-management applications; others—just beginning to be installed in aircraft—are sophisticated purpose-built systems.

One of the primary factors in the development of EFBs has been the reduction—and in some airplanes, the near-elimination—of paper reference materials on the flight deck. Nevertheless, advocates of EFBs say that among the benefits of the transition from paper to electronics are enhanced safety, increased efficiency and lower operating costs.

The U.S. Federal Aviation Administration (FAA), which in 2003 published Advisory Circular (AC) 120-76A, Guidelines for the Certification, Airworthiness and Operational Approval of Electronic Flight Bag Computing Devices—the first set of guidelines on this subject produced by civil aviation authorities—defines an EFB as “an electronic display system intended primarily for cockpit/flight deck or cabin use.”[1]

The AC guidelines are designed to assist aircraft operators and flight crews in transitioning from the use of paper products to EFBs. Similar guidelines have since been adopted by other civil aviation authorities, including the European Joint Aviation Authorities. [2]

“EFB devices can display a variety of aviation data or perform basic calculations (e.g., performance data, fuel calculations, etc.),” AC 120-76A says. “In the past, some of these functions were traditionally accomplished using paper references or were based on data provided to the flight crew by an airline’s ‘flight dispatch’ function. 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. These devices are sometimes referred to as auxiliary performance computers (APC) or laptop auxiliary performance computers (LAPC).”

Paper—in the form of paper manuals on operations specifications, printed checklists and minimum equipment lists, and pencil-and-paper calculations—has long been essential on the flight deck. For example, Boeing Commercial Airplanes estimates that a typical Boeing 777-200ER not equipped with an EFB carries about 77 pounds (35 kilograms) of paper manuals, paper checklists and other paper items on the flight deck.[3]

An EFB “basically reduces the required paper to a quick reference handbook,” says Boeing spokesman Jim Proulx. “That becomes the only manual that pilots need to have. Everything else is on the EFB.”[4]

Airbus, which has developed “Less Paper in the Cockpit” (LPC) software for EFBs in use in A320, A330 and A340 airplanes, says that the goal is to provide “a complete range of in-flight information [as part of] a modern approach to cockpit information management.”[5]

The transition from paper to electronics has been gradual.

U.S. Air Force Reserve Maj. Frederic S. Fitzsimmons, a researcher for the U.S. Air Force Academy Institute for Information Technology Applications, says that the concept of EFBs may have originated in general aviation.[6]

"As GPS [global positioning systems] receivers became more common and inexpensive, [general aviation] aircraft have had several moving-map-type devices available to them," Fitzsimmons says. "As these devices became more sophisticated, many began incorporating additional features. ... Within the last several years, these devices have incorporated electronic approach plates and airfield diagrams. ... With this advance ... simple EFBs were able to begin replacing much of the paper in cockpits."

The same technology was adapted to allow for EFB use by operators of business aircraft, corporate aircraft and commercial aircraft. Although EFBs originally were intended to provide electronic versions of checklists, manuals and navigation publications, the range of other possible uses has continued to increase.

In AC 120-76A, FAA says, "Operators have long recognized the benefits of using portable electronic computing devices, including commercially available portable computers, to perform a variety of functions traditionally accomplished using paper references. EFB systems may be approved for use in conjunction with or to replace some of the hard-copy material that pilots typically carry in their flight bags."

Civil Aviation Authorities Define Three EFB Classes

The AC and JAA Leaflet No. 36 contain similar descriptions of three classes of EFB hardware:

• Class 1 EFB systems usually are portable, commercial off-the-shelf (COTS)-based computer systems used for aircraft operations. They are connected to aircraft power through a certified power source and are not attached to a mounting device on the flight deck. No administrative control process is required before they can be used in an aircraft. Class 1 EFBs are considered portable electronic devices (PEDs);

• Class 2 EFB systems usually are portable, COTS-based computer systems used for aircraft operations. They are connected to aircraft power through a certified power source and, unlike Class 1 EFB systems, are connected during normal operations to a mounting device on the flight deck, and airworthiness approval is required before the devices may be used in an aircraft. Connectivity to avionics equipment is possible. Class 2 EFBs are considered PEDs; and,

• Class 3 EFB systems are installed systems (not PEDs) that require airworthiness approval. The certification requirements for Class 3 EFBs allow for applications and functions not performed using Class 1 and Class 2 EFBs, however. For example, Class 3 EFBs can accommodate moving-map software that also displays "own-ship" position—the position of the aircraft as it moves across the area depicted on the map.

AC 120-76A and Leaflet No. 36 define three types of EFB software applications:

• Type A software applications include "pre-composed, fixed presentations of data currently presented in paper format," JAA's Leaflet No. 36 says. The applications include flight crew operations manuals, company standard operating procedures, aircraft performance data, maintenance manuals, and data for airports and airport facilities. Type A software should be approved through the operational process but does not require airworthiness approval;

• Type B software applications include "dynamic, interactive applications that can manipulate data and presentation," Leaflet No. 36 says. The applications include performance calculations, weight-and-balance calculations, some interactive electronic aeronautical charts (without displays of own-ship position) and electronic checklists. Type B software should be approved through the operational process but does not require airworthiness approval; and,

• Additional software applications (described by JAA as "other" applications and by FAA as Type C software applications) are those not classified as Type A or Type B. Both FAA and JAA require full airworthiness approval for these applications, which include—according to a JAA list—those involving the display of information directly used by the flight crew to control aircraft attitude, speed or altitude; and those that would substitute for or duplicate a certified avionics system.

Data are incomplete on the extent to which EFBs are being used, but Airbus says that in mid-2005, LPC software for its Class 1 EFB systems was being used by 50 airlines worldwide.[7] The International Air Transport Association estimated that—also in mid-2005—thousands of Class 1 EFBs and Class 2 EFBs were in use.[8] Boeing said that only about 19 Class 3 EFBs were being used, all in B777 airplanes—the first airplane for which Class 3 EFB systems were approved.[9]

Devices that today would be considered Class 1 EFBs were in use several years before FAA's publication of its AC guidelines—as long ago as the early 1990s, when pilots for FedEx began using laptop computers on the flight deck for aircraft performance calculations.[10]

A published report says that FedEx was using the same software in 2004, when a pilot calculated—15 minutes before pushback of his McDonnell Douglas MD11 from Memphis, Tenn., U.S., for a flight to Tokyo, Japan—that the aircraft was too heavy for takeoff on the planned runway. Without the performance software, the solution would

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have been to offload cargo. Instead, the pilot used the software to evaluate several other possibilities and determined that conditions on a different runway were acceptable for takeoff.[11]

Other airlines, including Austrian Airlines, JetBlue Airways and Southwest Airlines, also incorporated laptop computers in the flight deck routine years before civil aviation authorities began developing guidelines.

The first Class 3 EFB was deployed in October 2003, when KLM Royal Dutch Airlines received the first B-777-200ER airplane equipped with Boeing EFBs. Since then, 18 other B-777 airplanes equipped with Class 3 EFBs have been delivered to KLM and three other airlines—Emirates, Malaysia Airlines and Pakistan International Airlines. Class 3 EFBs also will be installed in B-777 airplanes scheduled to be delivered in 2005 to EVA Airways Corp. and in 2006 to Air New Zealand.[12]

At Emirates, which took delivery of its first EFB-equipped B-777-300ER in March 2005, managers of the Flight Operations Department expressed "enthusiasm and high hopes" for the use of EFBs, says spokeswoman Frances Barton. Performance and documentation applications were implemented on the four B-777-300ER airplanes in service in June 2005, and other on-board information applications were being evaluated for eventual implementation on a total of 30 B-777s and on 45 Airbus A380 airplanes ordered by the airline.[13]

Proulx says that each of Boeing's Class 3 EFB systems includes two display units and two electronics units—one for the captain and the other for the first officer. Each pilot's system operates independently, and each includes two computers.

"The systems are doubly redundant unto themselves," Proulx says. "The captain's system is independent of the first officer's system, and within the system itself, there are double systems. However, the Boeing EFB can provide 'chart clips' so that one pilot's EFB display can show the image displayed on the other pilot's EFB; this allows one pilot to generate information for the other pilot's viewing."

The stand-alone units are not vulnerable to computer hackers (people who illegally gain access to and/or alter information in computer systems).

Airbus will introduce its class 3 EFBs in A380 airplanes, the first of which are scheduled for delivery in 2007 to Emirates, and later, on A350 airplanes.[14]

Cost Reduction Projected

In addition to enabling flight crews to reduce the amount of paper on the flight deck, EFBs have other advantages, including a reduction in expenditures.

"The business case for deploying EFBs considers many types of benefits to airlines," says an April 2005 FAA study. "Relative to traditional avionics, they come at a low initial cost, can be customized and are easily upgraded, making them an open-ended computing platform rather than a packaged system."[15]

Most areas in which cost-reduction is possible involve data management and data distribution, but projected savings also include training costs and medical costs associated with pilot injuries from carrying heavy flight bags filled with paper, the FAA study says.

Jerome Leullier, manager of operational methods and human factors at Airbus, cites several specific areas in which savings occur: "No paper for e-documentation and daily flight folders generation, [no] space for paper storage and [no] manual data transcription after the flight."[16]

In addition, David Massy-Greene and Amy Johnson, EFB specialists at Boeing, say, "Current takeoff and landing calculations are conservative and often based on early dispatch weight-and-balance information, which adds delay and cost to each flight. The EFB will reduce airline costs and increase payload by providing more accurate calculations based on real-time information. These calculations can result in lower thrust ratings, which reduce engine maintenance costs."[17]

The maintenance process also benefits from an EFB's electronic logbook application, which provides for the identification, recording and reporting of aircraft faults; and the transfer of the information to the EFB performance calculator. When maintenance personnel review the electronic logbook, complaints are legible—in contrast with some pilots' handwritten notations.[18]

Airbus has estimated that operating costs and maintenance costs could be reduced by as much as 5 percent for each airplane equipped with an EFB.[19]

In addition to cost-reduction benefits, calculations performed using EFB software reduce the possibility for human mathematical errors. The computer software also warns pilots if a number has been entered that is outside the anticipated range for a specific weight or function.

In a published report, Nicholas Sabatini, FAA associate administrator for regulation and certification, points to the error-finding software as a safety enhancement.

"Eliminating possibilities for humans to make errors raises the safety bar," Sabatini says.[20]

Michel Tremaud, senior director of customer services and head of safety management for Airbus, agrees.

"The use of EFBs reduces the risk of errors, particularly when operating in demanding conditions or under fatigue," Tremaud says. "This is particularly the case in terms of weight-and-balance computation, takeoff performance computations, especially when corrections, such as MEL conditions, have to be applied."[21]

EFB calculations also are more precise than those prepared by pilots using aircraft performance charts. Tremaud says that the results of EFB performance computations are more "optimized," compared with paper charts, which are always "conservative."

Moving Maps Improve Situational Awareness

EFBs also provide for increased safety during ground operations with airport surface moving map (SMM) displays designed to improve pilot situational awareness. Class 3 EFBs combine GPS technology with an electronic airport-taxi map to provide an indication of own-ship position and heading; Class 2 EFBs include a moving map but do not indicate own-ship position.

Massy-Greene and Johnson say that studies by government and industry have found that SMM displays are "the most powerful intervention for runway-incursion prevention" and that use of SMM displays with own-ship position could prevent nearly half of all runway incursion incidents.

"The evolution of the [SMM] function can increase capability, especially if it shares the situational awareness functionality provided to the airport ground traffic controller," they say. "Coupling of the airplane-based SMM with the airport-based situational display will provide the flight crew with complete airport situational assessment. The flight crew will have not only a full situational view but also be able to view the same data and assessment as the airport ground controller. This will lead to more effective communication and, therefore, increased safety."

In addition to safety benefits, the enhanced situational awareness also helps reduce taxi times and reduce delays.[22]

Display Screens Can Provide Cabin Surveillance

Some EFB systems can be linked to cameras that monitor the cabin and the cabin side of the flight deck door in compliance with a standard developed by the International Civil Aviation Organization (ICAO) for "a means ... for monitoring from either pilot's station the entire door area outside the flight crew compartment to identify persons requesting entry and to detect suspicious behavior or potential threat."[23]

Tom Mullan of ARINC says that his firm's Class 2 EFB includes video surveillance that allows the flight crew to monitor the flight deck door without the installation of dedicated video displays. The video is obtained from any number of cameras that are installed in the cabin and is displayed on an EFB screen.[24]

EFBs also provide for several improvements in communication, including the following:[25]

- A communications-management function allows an airline to select preferred communication methods for EFB applications. In many airplanes, the EFB is connected to the aircraft communications addressing and reporting system (ACARS) and the communications management unit (CMU) cabin terminal port; and,
- Distributed data management allows an airline to automatically manage data delivery to its airplanes by copying information onto CD-ROM (compact disc-read only memory) loaded into the EFB.

Transition From Paper Alters Workload

One of a series of studies conducted for FAA of human factors considerations involving the use of EFBs says that the transition from paper to EFBs could present problems for flight crews.

"It is important to understand how a new system such as an EFB will affect workload patterns," says the report by aviation human factors researchers. "Workload may be decreased in some ways and increased in other ways. Increased workload could result from inefficient design of the software or hardware, or even from limitations in the flexibility of using EFBs in relation to paper documents."[26]

The report says that the operator should understand in advance how workload patterns will change and should decide whether the changes will be acceptable. Any evaluation of the EFB-related workload should consider the time required to perform a specific task with an EFB, compared to the time required without an EFB. Related factors include the accessibility of the EFB controls and the EFB display, the amount of automation provided by the EFB and characteristics of the EFB software. Other considerations are whether errors would be more likely during periods of heavy workloads, how difficult error-recovery would be and whether efforts to resolve EFB problems would be likely to distract pilots from other tasks, the report says.

The report cites the following example:

An EFB may provide flight crews with a new capability, such as completing weight-and-balance calculations. This new responsibility may be in addition to the other tasks that the flight crew is used to performing, so in a sense, it is an increase in the flight crew's workload. Procedures should ensure that the workload associated with this type of new task is acceptable. For example, crews could be allowed to update weight-and-balance computation only while at the gate, rather than during taxi, or they could use these functions only to review or modify calculations while taxiing.

The workload required to manipulate electronic documents may exceed

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the workload required to manipulate paper documents. Although workload might increase with electronic documents, this negative quality is offset by other factors, such as the improved electronic search capabilities and the fact that documents are typically referenced in low workload conditions. Overall, the net increase in workload may be judged acceptable.

Instead of supporting new tasks, an EFB may allow flight crews to perform existing tasks more efficiently, such as looking up reference information from a flight manual. In this case, the design of the software-search procedure can affect the risk of getting lost in the process of searching for information, or the risk of becoming distracted by a search that results in too many choices. An appropriate design of the search procedure should mitigate these risks.

It may be hard to find a good viewing position for a portable EFB that shows electronic charts. The EFB is less flexible than paper in this sense. The reduced flexibility of positioning an EFB may affect the pilot's task by increasing head-down time, and as a consequence, workload.

The report also recommends that air carriers adopt policies explaining how crewmembers should use EFBs and discussing crew resource management, the potential for distractions caused by EFBs and strategies to be used to prevent distractions. Adoption of an EFB policy establishes a framework for developing procedures for EFB use, the report says.

"To address crew coordination issues, the policy should discuss who (the pilot flying or the pilot not flying) should use the device and under what conditions," the report says. "It should also address monitoring and confirmation duties of the crewmember who is not actively using the EFB. If two EFB units are on-board, the policy should also address any cross-checking that is required. If the EFB functions duplicate or overlap with other functions or information sources on the flight deck, the policy could describe the operator's philosophy for deciding which information source is primary and which are secondary."

The report says that all pilots should be proficient in operating EFB equipment before they are required to operate it during flight, and training should provide instruction on the operator's EFB policy, as well as individual EFB applications. Pilot proficiency should be evaluated through line checks and recurrent/continuing training, the report says.

Paper vs. Electronic: Differences Create Opportunities for Errors

For at least the next few years, as EFBs are added to flight decks, paper charts probably also will remain at hand, the human factors researchers say.[27]

"Even if the paper charts are removed from the flight deck, most pilots are so familiar with using paper charts that it will take some time for them to become as comfortable with electronic charts as they are with paper charts," they say.

They say that during training, pilots may require instruction on how to configure individual electronic charts and use them, especially if the electronic charts do not resemble the paper charts to which pilots are accustomed. The researchers recommend that the same symbology, general layout and information groupings used on paper charts should be used on electronic charts.

"Pilots are highly familiar with the information and visual structure of paper charts," the researchers say. "These users have developed highly efficient and individualized strategies for retrieving chart information for reference and planning purposes. These strategies are so well ingrained that pilots can have difficulty switching between paper charts from different sources, which may vary relatively little in format. ... Users will need to spend time developing and learning new strategies for using electronic charts. If the electronic chart is created based on a totally new structure, developing these strategies may be challenging at first, and the challenges may last for a long time. Also, confusion and errors are more likely if pilots do not find the electronic information where they expect it to be, based on their experience with paper charts."[28]

In addition to training programs, an operator that is introducing EFBs as part of a transition to a paperless cockpit must have a reliable alternate method of providing required information to flight crewmembers during the transition.

"During this period, an EFB system must demonstrate that it produces records that are as available and reliable as those provided by the current paper information system," says AC 120-76A.

To ease the transition, several actions are recommended, including "system design, separate and backup power sources, redundant EFB applications hosted on different EFB platforms, paper products carried by selected crewmembers, complete set of sealed paper backups in cockpit and/or procedural means," AC 120-76A says.

A backup plan in the event of an EFB failure during the transition period could include carrying paper documents in the airplane for a specified time period, using a printer to print data required for the flight or using an airplane fax machine to receive equivalent paper documents if required, the AC says.

EFBs Foster Human Factors Research

Human factors researchers at the

U.S. Department of Transportation Volpe National Transportation Systems Center have conducted several studies of EFBs, which they say present "a host of human factors challenges."[29]

In a 2000 report, which contained a list of human factors topics for consideration by EFB designers and evaluators, the specialists discussed some of those challenges:[30]

Using an EFB requires effort. There may be effort involved in locating and orienting the display for use and there is effort in looking at the display, processing the information and making any necessary entries. Data entry can produce particularly long head-down times and high workload. Visual scanning of the EFB (without data entry) does not require as much effort, but it is still an additional task for the pilot. The additional workload required to use an EFB may distract the pilot from higher-priority time-critical tasks during critical phases of flight.

In a 2003 report, they said that, although EFBs help pilots to conduct flights more safely and more efficiently, the devices "could have negative side effects if not implemented appropriately."[31]

As an example, they again cited the potential distraction presented by an EFB:

During high workload situations, such as takeoff and landing, entering data on the EFB may distract the crew from essential functions, such as visual scanning for air traffic out the window or scanning of aircraft instruments. Data entry tasks should be avoided during these phases of flight. If data entry is required, it should be limited to a single key press. For example, to indicate that the "Climbout Checklist" has been completed, the pilot may enter a yes/no response to an EFB inquiry.

If, however, the EFB is used as a display of real-time information useful during landing (e.g., if the EFB displays nearby traffic during landing) and only requires occasional scanning that the pilot can incorporate into his/her task schedule, the additional workload may be acceptable. An operational evaluation may be necessary to ensure this conclusion.

A spokesman for the U.K. Civil Aviation Authority (CAA) says that the CAA has a similar concern.

"Provided the precautions and concerns addressed in AC 120-76A and [Leaflet No.] 36 are addressed properly and with appropriate training and operational oversight, EFBs have the potential to be able to increase safety," says Jonathan J. Nicholson. "However, inappropriate use by crews or failure to observe appropriate limitations and precautions could have an adverse effect."[32]

The human factors researchers said in their 2003 report that an EFB with more built-in automation may be preferable during periods of heavy workload.

"For example, if some items in an emergency checklist are completed through aircraft sensors, the pilot's workload may not be impacted negatively by using the EFB, as compared with the paper checklist," the report said. "Some EFBs that have knowledge of aircraft system status may have built-in limits, such as the inability to exercise certain functions below 10,000 feet altitude."[33]

This concern also was addressed in AC 120-76A, which says, "EFB software should be designed to minimize flight crew workload and head-down time. ... Complex, multi-step data-entry tasks should be avoided during takeoff, landing and other critical phases of flight."

Ease of Access Determines Usefulness

The location of an EFB is a critical element in the length of time a pilot spends completing a task using the device.

The human factors researchers say, "The location and accessibility of the EFB display and controls, the amount of automation and the usability of the EFB software will all affect the time it takes to complete a task using the EFB."[34]

AC 120-76A and Leaflet No. 36 both contain guidelines for the design of a mounting device to be used with a Class 2 EFB:

The mounting device ... may not be positioned in such a way that it obstructs visual or physical access to aircraft controls and/or displays, flight crew ingress or egress, or external vision. The design of the mount should allow the user easy access to the EFB controls and a clear view of the EFB display while in use. ...

The device should be mounted so that the EFB is easily accessible when stowed. When the EFB is in use ... , it should be within 90 degrees on either side of each pilot's line of sight. ... A 90-degree viewing angle may be unacceptable for certain EFB applications if aspects of the display quality are degraded at large viewing angles (e.g., the display colors wash out or the displayed color contrast is not discernible at the installation viewing angle). In addition, consideration should be given to the potential for confusion that could result from presentation of relative directions (e.g., positions of other aircraft on traffic displays) when the EFB is positioned in an orientation inconsistent with that information. For example, it may be misleading if own aircraft heading is pointed to the top of the display and the display is not aligned with the aircraft longitudinal axis. Each EFB system should be evaluated with regard to these requirements.

Pilots who use Class 1 EFB systems and Class 2 EFB systems that are not mounted during use should be "de-

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signed and used in a manner that prevents the device from jamming flight controls, damaging flight deck equipment or injuring flight crewmembers should the device move about as a result of turbulence, maneuvering or other action," the researchers say.

In addition, EFBs that are attached to kneeboards should be comfortable, convenient to attach and easy to remove in an emergency; pilots should know what to do with an EFB during an emergency landing, when keeping a kneeboard on the knee might not be the safest action.

Guidance material from regulatory authorities requires that portable EFBs be stowed when they are not in use, and the report[33] recommends that the device (like all others used on the flight deck) have a designated space, both during use and during stowage.

"EFB units may move unexpectedly during significant accelerations," the report says. "For example, a unit left on an unused seat may fall off the seat during turbulence. The next time the pilot attempts to use the device, finding the unit will cause pilot distraction, at the least.

"During takeoff and landing, the EFB may need to be stowed in order to prevent injuries to the crew in case of sudden aircraft accelerations, similar to the requirement for stowing tray tables for passengers."

Despite these cautions, the researchers say that portable EFBs have some advantages, such as giving the pilots the ability to place the device in the best position for any task, and the ability to move the display screen to avoid glare.

Other Reports Recommend Methods of Evaluation

Additional reports, prepared after publication of AC 120-76A, include one that described tools for evaluating the usability of EFBs[36] and another that reviewed available EFB equipment.[37]

The evaluation tools—a short tool designed for a brief evaluation of an EFB system and a longer, more detailed tool designed for a more comprehensive evaluation—are intended to allow system designers, aircraft operators and aircraft certification specialists to assess human factors aspects of EFB systems.

The industry review, published in February 2005, was intended as a "primer on who is involved in the industry and what their efforts are." The document describes characteristics of EFB systems and provides other information, including the applications they support and their potential customers

In their discussion of human factors considerations, the researchers say that although manufacturers believe that EFB failures are rare, flight crew training should ensure that crewmembers know what procedures to follow if one EFB unit—or more—fails.[38]

EFB failures should be "graceful," the human factors researchers say, "in the sense that they can be recovered from easily, with minimum disruption to flight crew tasks and workload. If failures are not easily recognized, if failures are difficult to recover from or if procedures for handling failures have not been developed in advance, crew workload and performance may suffer significantly at the time of an EFB failure."

In addition, they say that flight crewmembers should know which information to use if the information supplied by an EFB differs from that provided by other flight deck systems, such as a flight management system or engine indication and crew-alerting system.

"Whether or not there is any communication between aircraft systems and the EFB, from the perspective of a crewmember, the EFB is just another tool for him/her to use," the researchers say. "If there are inconsistencies or redundancies in the information provided by the different automation systems ('tools') or information sources, there will be confusion and increased potential for errors."

Use of EFBs is "expanding apace," Proulx says. In addition to scheduled deliveries of B-777s with Class 3 EFBs to two airlines in 2005 and 2006, Class 3 EFBs will be standard on the B-787.

"The early adopters have adapted; getting into the next level is going to be the difficult part, largely because, if money is tight and your priority is just keeping your airline flying, you don't have a lot of money for extras," he says.

Leullier says that all A380 airplanes will be equipped with Class 3 EFBs, and that "the development/retrofit has already begun for the A320 family and A330/340 (Class 2/3)."

Defalque says that the number of EFBs in commercial airplanes will continue to increase, especially as more A350, A380, B-777 and B-787 airplanes come into service, and that eventually, all new Western-built transport category aircraft will be equipped with them.

Devices Could Prove Central to Information Management

In addition to current applications, EFBs are designed to accommodate new functions in the future. Possibilities include airport familiarization to help pilots operating at unfamiliar airports by providing photographs and other relevant airport information; controller-pilot data link communications; and en route moving maps with ownship position.[39]

Divya C. Chandra, an aviation human factors researcher at the Volpe center, says that EFBs "could well play a central role in the future of flight deck information management. In the future, EFBs may develop uses that we cannot even foresee today."[40]

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