# Flight Safety
## D I G E S T

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# ‘Paperless Cockpit’ Promises Advances in Safety, Efficiency

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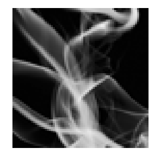



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# ‘Paperless Cockpit’ Promises Advances in Safety, Efficiency

**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.**

— FSF EDITORIAL STAFF

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

"Operators have long recognized the benefits of using portable electronic computing devices."

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 (JAA; see Appendix, page 11).[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 "precomposed, 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 B-777 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 MD-11 from Memphis, Tennessee, 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 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]

**Class 3 EFB systems are installed systems (not PEDs) that require airworthiness approval.**

Other airlines, including Austrian Airlines, JetBlue Airways and

The captain of a Boeing 777 adjusts a Class 3 electronic flight bag.
(Photo: The Boeing Co.)

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

**"The use of EFBs reduces the risk of errors."**

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.

**An EFB may allow flight crews to perform existing tasks more efficiently.**

## 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 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 onboard, 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.

**"It will take some time for [pilots] to become as comfortable with electronic charts as they are with paper."**

"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.*

**The devices “could have negative side effects if not implemented appropriately.”**

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 "designed 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 own-ship 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] ■

## Notes


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**LEAFLET No. 36: APPROVAL OF ELECTRONIC FLIGHT BAGS (EFBs)**

**1. PURPOSE**

The material contained in this Leaflet has been issued in accordance with Chapter 10 of the Administrative & Guidance Section 4: Operations, Part Three: Temporary Guidance Leaflets and therefore is authorised for use on voluntary basis until such time as the material has been subjected to NPA process.

**2. SCOPE**

2.1 Traditionally all documentation and information available to flight crew for use on the flight deck has been in paper format. Much of this information is now available in electronic format and the purpose of this leaflet is to give guidance to operators on gaining approval from their National Authority for the use of electronically processed information.

2.2 It is not intended to impose additional requirements in respect to basic information and data sources. The operator remains responsible for ensuring the accuracy of the information used and that it is derived from verifiable sources. The approval of EFBs is intended to cover the different methods of storing, retrieving and use of this information.

2.3 This guidance material is designed to cover airworthiness and operational criteria for the approval of Electronic Flight Bags (EFBs).

**3. REFERENCE DOCUMENTS**

**3.1 Related Requirements**

CS/FAR 25.1301, 25.1309, 25.1316, 25.1321, 25.1322, 25.1431, 25.1581
CS/FAR 23.1301, 23.1309, 23.1321, 23.1322, 23.1431, 23.1581
CS/FAR 27.1301, 27.1309, 27.1321, 27.1322, 27.1581
CS/FAR 29.1301, 29.1309, 29.1321, 29.1322, 29.1431, 29.1581
Appendices A to CS-27 and CS-29: Instructions for Continued Airworthiness
JAR-OPS 1.110, 1.130, 1.135, 1.140, 1.150, 1.155, 1.175, 1.185, 1.200, 1.290, 1.625, 1.915, 1.920, 1.965, 1.1040, 1.1045, 1.1055, 1.1060, 1.1065, 1.1071
JAR-OPS 3.243, 3.845, 3.865 as amended by NPA-OPS-8
National operating regulations.

**3.2 Related Guidance Material**

**3.2.1 JAA**

| | |
|---|---|
| AMC 25.1581 | Appendix 1 – Computerised Aeroplane Flight Manual |
| INT/POL/25/14 | Human Factors Aspects of Flight Deck Design |
| TGL No. 29 | Guidance Concerning The Use Of Portable Electronic Devices On Board Aircraft. |
| EUROCAE ED-12() | Software Considerations in Airborne Systems and Equipment |
| EUROCAE ED-14() | Environmental Conditions and Test Procedures for Airborne Equipment |
| UL 1642 | Underwriters Laboratory Inc (UL) Standard for Safety for Lithium Batteries |

**3.2.2 FAA**

| | |
|---|---|
| AC 91.21-1A | Use of Portable Electronic Devices Aboard Aircraft |
| AC 120-64 | Operational Use & Modification of Electronic Checklists |
| AC 120-74 | Flight Crew Procedures During Taxi Operations |
| AC 120-76A | Guidelines for the Certification, Airworthiness and Operational Approval of Electronic Flight Bag Computing Devices. |

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| | |
|---|---|
| TSO-C165 | Electronic Map Display Equipment for Graphical Depiction of Aircraft Position |
| RTCA DO-160() | Environmental Conditions and Test Procedures for Airborne Equipment |
| RTCA DO-178() | Software Considerations in Airborne Systems and Equipment |
| RTCA DO-257A | Minimum Operational Performance Standards for the Depiction of Navigation Information on Electronic Maps |
| Volpe Center Report | Human Factors Considerations in the Design and Evaluation of Electronic Flight Bags (EFBs) Version 2 |

**4. DEFINITIONS**

**4.1 Aircraft Administrative Communications (AAC).** AAC data link receive/transmit information that includes but is not limited to, the support of applications identified in Appendices A and B of this Leaflet. Aeronautical Administrative Communications (AAC) are defined by ICAO as communications used by aeronautical operating agencies related to the business aspects of operating their flights and transport services. The airlines use the term Airline Operational Communication (AOC) for this type of communication.

**4.2 Controlled PED.** A controlled PED is Portable Electronic Device that is subject to administrative control by the company. This will include, inter alia, tracking the location of the devices to specific aircraft or persons and ensuring that no unauthorised changes are made to the hardware, software or databases. A Controlled PED will also be subject to procedures to ensure that it is maintained to the latest amendment state.

**4.3 Data Connectivity for EFB Systems.** Supporting either uni or bi-directional data communication between the EFB and the aircraft systems (e.g., avionics).

**4.4 Electronic Flight Bag (EFB).** 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.). 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 operator's "flight dispatch" organisation. 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).

**4.5 EFB Administrator.** The EFB Administrator is the person appointed by the operator, held responsible for the administration of the EFB system within the company. The EFB administrator is the primary link between the operator and the EFB system supplier.

He/she will be the person in overall charge of the EFB system and will be responsible for ensuring that any hardware conforms to the required specification and that no unauthorised software is installed. He/she will also be responsible for ensuring that only the current version of the application software and data packages are installed on the EFB system.

**4.6 EFB System.** An EFB system includes the hardware and software needed to support an intended function.

**4.7 Hosted Application.** Software installed on an EFB system that allows specific operational functionality.

**4.8 Interactive Information.** Information presented on the EFB that, via software applications, could be selected and rendered in a number of dynamic ways. This includes variables in the information presented based on data-oriented software algorithms, concepts of de-cluttering, and "on-the-fly" composition as opposed to pre-composed information.

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**4.9 Mounting Device.** May include arm-mounted, kneeboard, cradle, or docking-stations, etc. May have ship's power and data connectivity. May require quick-disconnect for egress.

**4.10 Portable Electronic Device (PED).** JAA TGL No. 29 and FAA Title 14 CFR § 91.21 define PEDs.

**4.11 Pre-Composed Information.** Information previously composed into a static composed state (non-interactive). The composed displays have consistent, defined and verifiable content, and formats that are fixed in composition. Applications based on pre-composed information may support "contextual access" like hyperlink, bookmark.

## 5. SYSTEM DESCRIPTION AND CLASSIFICATION OF EFB Systems

This section is divided into two parts. The first part deals with the host platform i.e. the hardware used to run the software programs and the second part deals with the software programs or applications installed to provide the relevant functionality. For information, a matrix showing the relationship between airworthiness and operational approval processes is provided in Appendix E.

### 5.1 Hardware Classes of EFB Systems

This Leaflet defines three hardware classes of EFB systems, Class 1, 2, and 3.

#### 5.1.1 Class 1

Class 1 EFB systems are:

- Generally Commercial-Off-The-Shelf (COTS)-based computer systems used for aircraft operations,
- Portable,
- Connect to aircraft power through a certified power source,
- Not attached to an aircraft mounting device,
- Considered as a controlled PED,
- Normally without aircraft data connectivity except under specific condition (see Section 6),
- Class 1 EFB systems do not require airworthiness approval.

#### 5.1.2 Class 2

Class 2 EFB systems are:

- Generally COTS-based computer systems used for aircraft operations,
- Portable,
- Connect to aircraft power through a certified power source,
- Connected to an aircraft mounting device during normal operations,
- Considered as a controlled PED,
- Connectivity to Avionics is possible,
- Class 2 EFB systems require airworthiness approval as described in Section 6.

#### 5.1.3 Class 3

Class 3 EFB systems are installed equipment requiring an airworthiness approval. This approval should cover the integrity of the EFB hardware installation (e.g. server, display, keyboard, power, switching), including hardware and software qualification. Such aspects as the human machine interface should also be addressed.

### 5.2 Software Applications for EFB Systems

The functionality associated with the EFB System depends upon the applications loaded on the host. The classification of the applications into two Types (A and B) is intended to provide clear divisions between the scope and therefore the approval process applied to each one. Although guidelines and examples are provided in this leaflet to provide guidance as to the Type associated with a particular application, there is still the potential for misclassification. Applicants should be aware of two particular issues. The Type of application will influence the level of participation of the operations authority i.e. National Authority Flight Operations Inspectorate (FOI) or Joint Operational Evaluation Board (JOEB) and indeed the involvement or otherwise of the airworthiness authorities in the assessment exercise. For example, a misclassification may later be shown to have impacted the underlying airworthiness approval granted for the aircraft systems. In particular where there is data connectivity or interactive information the assumptions made by the Original Equipment Manufacturer (OEM) during initial certification may no longer hold e.g. data integrity, accuracy of performance calculations, primary use versus situational use. Therefore, if there is any doubt as to the classification of an application, applicants should seek advice early on in the approval process from either the respective JOEB Team or Central JAA Operations Directorate.

**5.2.1 Type A**

Type A software applications include pre-composed, fixed presentations of data currently presented in paper format. Type A software applications:

- May be hosted on any of the hardware classes
- Require Operational approval. This may be undertaken at the National Authority FOI level.
- Do not require an airworthiness approval
- Typical examples of Type A software applications may be found in Appendix A.

**5.2.2 Type B**

Type B software applications include dynamic, interactive applications that can manipulate data and presentation. Type B applications:

- May be hosted on any of the hardware classes
- Require Operational approval. This will be undertaken at the JOEB level or where a JOEB does not exist for the particular aircraft type, the Central JAA may delegate to a National Authority FOI.
- Do not require an airworthiness approval
- Typical examples of Type B software applications may be found in Appendix B.

**6. AIRWORTHINESS APPROVAL**

The following airworthiness criteria are applicable to EFB installation.

**6.1 EFB Hardware Approval Process (Host Platform)**

**6.1.1 Class 1 EFB**

A Class 1 EFB does not require an airworthiness approval because it's a non-installed equipment however paragraph 6.1.1.a) through 6.1.1.d) here below should be assessed if relevant. During the operational approval process an assessment should be made of the physical use of the device on the flight deck. Safe stowage, crashworthiness, security and use under normal environmental conditions including turbulence should be addressed.

**a) EMI Demonstrations**
For the purpose of EMI demonstrations, EFB Class 1 devices may be considered as PEDs and should satisfy the criteria contained within TGL No. 29 or AC 91.21-1A. If the EFB system is to be used during critical phases of flight (e.g., during take-off and landing), further EMI demonstrations (laboratory, ground or flight test) are required to provide greater assurance of non-interference and ensure compatibility. For use during critical flight phases, the EFB system should comply with the requirements of ED-14()/DO-160() Section 21, Emission of Radio Frequency Energy.

**b) Lithium Batteries**
During the procurement of Class 1 EFBs, special considerations should be given to the intended use and maintenance of devices incorporating lithium batteries. In particular, the operator should address the following issues:

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- Risk of leakage
- Safe storage of spares including the potential for short circuit
- Hazards due to on-board continuous charging of the device, including battery overheat

As a minimum specification, the lithium battery incorporated within the EFB device should have been tested to Underwriters Laboratory Inc (UL) Standard for Safety for Lithium Batteries reference UL 1642. The operator is responsible for the maintenance of EFB system batteries and should ensure that they are periodically checked and replaced when required.

**c) Power Source**
The EFB power source should be designed such that it may be deactivated at any time. Where there is no possibility for the flight crew to quickly remove or un-plug the power to the EFB system, a clearly labelled and conspicuous means (e.g., on/off switch) should be provided. Circuit breakers are not to be used as switches; their use for this purpose is prohibited.

In order to achieve an acceptable level of safety, certain software applications, especially when used as a source of required information, may require that the EFB system have access to an alternate power supply.

**d) Data Connectivity**
Data connectivity to other systems is not authorised except if connected to a system completely isolated from the avionics/aircraft systems (e.g., EFB system connected to a transmission media that receives and transmits data for AAC purposes on the ground only). Any other type of data connectivity requires an airworthiness approval.

**6.1.2 Class 2 EFB**

A Class 2 EFB requires an airworthiness approval. However, this approval is limited in scope to the mounting device, crashworthiness, data connectivity and EFB power connection.

An evaluation of the EFB mounting device and flight deck location should be conducted as described below:

**a) Design of Mounting Device**
The mounting device (or other securing mechanism) that attaches or allows mounting of the EFB system, 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 following design practices should be considered:

(i) The mount and associated mechanism should not impede the flight crew in the performance of any task (normal, abnormal, or emergency) associated with operating any aircraft system.

(ii) Mounting devices should be able to lock in position easily. Selection of positions should be adjustable enough to accommodate a range of flight crewmember preferences. In addition, the range of available movement should accommodate the expected range of users' physical abilities (i.e., anthropometrics constraints). Locking mechanisms should be of the low-wear type that will minimize slippage after extended periods of normal use. Crashworthiness considerations will need to be considered in the design of this device. This includes the appropriate restraint of any class device when in use.

(iii) A provision should be provided to secure or lock the mount in a position out of the way of flight crewmember operations when not in use.

(iv) Mechanical interference issues of the mount, either on the side panel (side stick controller) or on the control yoke in terms of full and free movement under all operating conditions and non-interference with buckles etc. For yoke mounted devices Original Equipment Manufacturer (OEM) data should be obtained to show that the mass inertia effect on column force has no adverse affect on the aircraft handling qualities.

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(v) If the EFB requires cabling to mate with aircraft systems or other EFBs, and if the cable is not run inside the mount, the cable should not hang loosely in a way that compromises task performance and safety. Flight crewmembers should be able to easily secure the cables out of the way during aircraft operations (e.g., cable tether straps).

(vi) Cables that are external to the mount should be of sufficient length to perform the intended tasks. Cables too long or short could present an operational or safety hazard.

**b) Placement of Mounting Device**
The device should be mounted so that the EFB is easily accessible when stowed. When the EFB is in use (intended to be viewed or controlled), it should be within 90 degrees on either side of each pilot's line of sight. This requirement does not apply if the information is not being directly monitored from the EFB during flight. For example, an EFB may generate takeoff and landing V-speeds, but these speeds are used to set speeds bug or are entered into the FMS, and the airspeed indicator is the sole reference for the V-speeds. In this case, the EFB system need not be located in the pilot's primary field of view. 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 colours wash out or the displayed colour 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. (See CS-23.1321 and CS-25.1321.)

**c) EMI Demonstrations, Lithium Batteries, Power Source**
In respect of the EMI demonstrations, use of lithium batteries and power source, see Paragraphs 6.1.1 a), b) and c) above.

**d) EFB Data Connectivity**
EFB data connectivity should be validated and verified to ensure non-interference and isolation from aircraft systems during transmission and reception.

**6.1.3 Class 3 EFB**

A Class 3 EFB is considered as installed equipment and therefore requires an airworthiness approval. Assessment of compliance with the airworthiness requirements would typically concentrate on two areas:

- The intended function and safety (e.g., security and integrity), applicable only to the interfaces with the avionics data sources and not to the software applications. The failure modes of the interface between the EFB and its avionics data sources should be assessed under normal and fault conditions. The assessment of safety and integrity of the software application should be addressed through the approval of the application itself (see Section 6.2).
- Hardware and software qualification should be conducted in accordance with the agreed Design Assurance Level (DAL) for the system and its interfaces. Note: DAL attribution at this stage (empty platform) may prohibit hosting of future software applications due to inconsistency between the criticality of the future software application and the platform DAL.

A Class 3 EFB may form part of a host platform (i.e., a network server) supporting other functions such as central maintenance. Such functions are considered to be outside of the scope of this leaflet and their approval should be conducted in accordance with normal certification procedures.

For a Class 3 EFB a human factors assessment should be conducted. At this stage the evaluation is restricted to the EFB hardware resources comprising display, keyboard, switches, annunciators, etc. However, in order to assess the human factors aspects of these devices, it may be necessary to host emulation software on the platform. This may be a dedicated software package developed purely for the purposes of conducting the assessment or be one or more of the intended EFB software applications. The human factors assessment should be conducted in accordance with the criteria applied during the aircraft type design or modification exercise and identified within the aircraft

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certification basis. If no prior human factors requirements have been applied, the applicant should follow the process described in Appendix D.

**6.1.4 Certification Documentation**

**a) Aircraft Flight Manual**
For Class 2 and 3 EFB the Aircraft Flight Manual (AFM) should contain any limitations affecting the use of the EFB system e.g., a statement that a particular function is not intended as a primary navigation reference. Note: under certain circumstances a placard mounted adjacent to the EFB display might also be warranted. The AFM should also make reference to any applicable guidelines for application developers, operators and national authorities – see chapter 6.1.4.b below.

**b) Guidelines for EFB Application Developers**
The guideline document should provide a set of requirements and guidelines to design, develop and integrate software applications into the EFB host platform. It is intended primarily for use by software application developers, but may also be of use to the operator and the JOEB and/or National Authority. The guideline should address at least the following:

- A description of the architecture for the host platform
- Information necessary in order to define a software application, including library routines etc.
- The EFB Design Assurance Level (DAL) and any assumptions, limitations or risk mitigations made in support of this
- Information necessary to ensure development of a software application consistent with the avionics interface and the human machine interface, that is also accurate, reliable, secure, testable, and maintainable
- Rules of co-habitation of any new software application with those already approved
- Guidelines on how to integrate any new software application into the platform
- A quality assurance process for developing software applications in the context of the host platform

**6.2 EFB Software Applications (Type A and B)**

Type A and B software applications do not require airworthiness approval, but should be approved through the operational approval process. Examples of Type A and Type B software applications, based mainly on FAA AC 120-76A, are given in Appendix A and B of this leaflet respectively. Some differences with FAA AC 120-76A have been introduced and are highlighted in these appendices. If a software application is not listed in these appendices and does not clearly fall into the existing definitions of Section 5.2, advice should be sought from the Central JAA or relevant JOEB Team, or the responsible National Authority.

**a) Applications Ineligible for Type A or Type B EFB Classification**
It should be noted that, unlike FAA AC 120-76A, this Leaflet does not include a Type C software application classification. The JAA policy is that any software application not falling within the scope of Type A or Type B should undergo a full airworthiness approval. This is consistent with the FAA policy for Type C software applications under the Advisory Circular, but eliminates the confusion of what is Type C EFB and what is normal aircraft function. This has been a particular issue with Class 3 hardware platforms where other non-EFB functions may be hosted requiring separate airworthiness approval. By removing Type C, in terms of airworthiness assessment all non Type A and Type B software applications are treated the same as non-EFB functions. Examples of software applications that the JAA consider to be ineligible for Type A or Type B EFB classification are provided in Appendix C.

**b) Specific Considerations for Performance and Electronic Checklist Applications**
Although the airworthiness authority is not directly involved in the approval of Type B software applications such as performance calculations (weight & balance, take-off and landing performance) and electronic checklist, they may become indirectly involved.

Performance applications are typically derived from Computerised AFM Information, approved against the applicable airworthiness regulations. Only certain modules of the performance program are

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approved, and then against a particular program revision and a particular host e.g., Personal Computer. With performance Type B software applications the operations authority (JOEB or National Authority) requires assurance that the resulting data, through software derivation, customisation or optimisation, provides performance figures that are consistent with the approved computerised aircraft flight manual information. If there is any concern, the operations authority may wish to seek advice from airworthiness performance specialists to assist in the validation of these types of software application. In general, this involves checking that the EFB derived performance calculations provides consistent results when compared with calculations from the approved AFM modules.

With electronic checklists, there is already regulatory guidance material published on the subject e.g., FAA AC 120-64. The concern here is where the EFB software application is customised or changed through the user-modifiable partition such that the electronic checklist differs from the approved procedures contained within the AFM. Of particular concern are changes affecting the approved Abnormal and Emergency Procedures. Again, where there are concerns, the operations authority should consult with the respective airworthiness authority team.

## 7 OPERATIONAL APPROVAL

The Authority will consider applications from operators to use an EFB system on a case-by-case basis using the process described hereafter. Operators planning to implement the use of EFB systems will need to demonstrate to the Authority that the EFB system is robust and will not provide inaccurate or misleading information to crews.

The operator may demonstrate the fidelity and reliability of the system in a number of ways. Where it is the intention to start EFB operations with no paper back up a full Operational Risk Assessment and suitable means of mitigation against failure or malfunction will be required. Alternatively, the operator may choose to keep the paper back up, as a cross check against the EFB information and as a means of mitigation against failure or malfunction. A combination of the above methods where some risk assessment and limited paper back up is carried may also be used at the discretion of the authority. The final Operational Evaluation Test (see section 7.7) will depend on the method used.

Note: Where the term Authority is used in this Section, it applies to either the JOEB or the National Authority depending on who has primary responsibility for conducting the assessment. Ultimately an individual operator would expect to receive an operational approval from their National Authority.

### 7.1 Operational Risk Analysis

The Authority will need to be satisfied that the operator has considered the failure of the complete EFB system as well as individual applications including corruption or loss of data and erroneously displayed information.

The objective of this process is to demonstrate that the software application achieves at least the same level of integrity and availability as the "traditional" means that it is intended to replace

#### 7.1.1 Scope

The analysis will be specific to the operator concerned but will need to address at least the following points:

- Minimisation of undetected erroneous application output
- Ease or otherwise to detect erroneous outputs from the software application
    - Description of corruption scenarios
    - Description of mitigation means (crew monitoring)

- Upstream development quality process
    - Reliability of root data used in applications (qualified/verified input data)
    - Application verification and validation checks

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  - Partitioning of application software having safety effect from application software without safety effect e.g., partitioning of Type A, B from other application.

- Description of the mitigation means following detected loss of application, or detected erroneous output due to internal EFB error e.g., availability of back up data, procedures etc. This may be in the form of an alternative EFB possibly supplied from a different power source or some form of paper back up system e.g., Quick Reference Handbook (QRH).

The operator may then propose to the Authority that the EFB system be used as an alternative system to paper documentation. The proposal to the Authority should specify which paper documentation need not be carried and/or any operational credit sought. The Authority may require a trial period during which paper documentation is retained to confirm the robustness of the system.

The impact of the EFB system on the Minimum Equipment List (MEL) should be assessed. The operator should demonstrate how the availability of the EFB is confirmed by pre-flight checks. Instructions to flight crew should clearly define actions to be taken in the event of any EFB system deficiency and whether dispatch is allowed.

**7.2 Human Machine Interface Assessment for Type A and B Software Applications**

The operator will need to carry out an assessment of the human machine interface and aspects governing Cockpit Resource Management (CRM), when using the EFB system. This should include a review of the complete system to include at least the following points.

- Human/machine interface
- Legibility of text
- Approach/departure and navigation chart display
- Responsiveness of application
- Off-screen text and content
- Active regions
- Managing multiple open applications and documents
- Messages and the use of colours
- System error messages
- Data entry screening and error messages

Note: Further guidance and means of compliance are provided in Appendix D.

**7.3 Flight Crew Operating Procedures.**

**7.3.1 Procedures for Using EFB Systems with other Flight Deck Systems**

Procedures should be designed to ensure that the flight crew know which aircraft system (e.g., Engine Indicating and Crew Alerting System (EICAS), Flight Management System (FMS), or EFB system) to use for a given purpose, especially when both the aircraft and EFB systems provide similar information. Procedures should also be designed to define the actions to be taken when information provided by an EFB system does not agree with that from other flight deck sources, or when one EFB system disagrees with another. If an EFB system generates information similar to that generated by existing cockpit automation, procedures should clearly identify which information source will be primary, which source will be used for back up information, and under what conditions to use the back up source. Whenever possible and without compromising innovation in design/use, EFB/user interfaces should be consistent (but not necessarily identical) with the flight deck design philosophy.

**7.3.2 Flight Crew Awareness of EFB Software/Database Revisions**

The operator should have a procedure in place to allow flight crews to confirm prior to flight the revision number and/or date of EFB application software including where applicable, database versions. However, flight crews should not be required to confirm the revision dates for other databases that do not adversely affect flight operations, such as maintenance log forms, a list of airport codes, or the Captain's Atlas. An example of a date sensitive revision is an aeronautical chart

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database on a 28-day AIRAC revision cycle. Procedures should specify what actions to take if the software applications or databases loaded on the EFB system are out-of-date.

#### 7.3.3 Procedures to Mitigate and/or Control Workload

Procedures should be designed to mitigate and/or control additional workloads created by using an EFB system. The operator should develop procedures such that both flight crewmembers do not become preoccupied with the EFB system at the same time. Workload should be apportioned between flight crewmembers to ensure ease of use and continued monitoring of other flight crew functions and aircraft equipment. These procedures should be strictly applied in flight and should specify the times at which the flight crew may not use the EFB system.

#### 7.3.4 Defining Flight Crew Responsibilities for Performance Calculations

Procedures should be developed that define any new roles that the flight crew and dispatch office may have in creating, reviewing, and using performance calculations supported by EFB systems.

### 7.4 Quality Assurance

The operator should document procedures for the quality control of the EFB system. This should detail who will be in overall charge of the EFB system, i.e. the EFB Administrator, and who will have authority to authorise and activate amendments to the hardware and software.

Procedures should be established for the maintenance of the EFB system and how unserviceabilities and failures will be dealt with to ensure that the integrity of the EFB system is assured. Maintenance procedures will also need to include the handling of updated information and how this will be accepted and then promulgated in a timely and complete format to all users and aircraft platforms.

Should a fault or failure of the system come to light it is essential that such failures are brought to the immediate attention of the flight crew and that the system is isolated until rectification action is taken. As well as back up procedures to deal with system failures a reporting system will need to be in place so that any action necessary, either to a particular EFB system, or to the whole system, is taken in order to prevent the use of erroneous information by flight crews.

The EFB system will need to be secure from unauthorised intervention. This should include the use of password protected system updates as well as physical security of the hardware. Measures should also include the control of laptop software installations to prevent use of unauthorised data.

### 7.5 Role of the EFB Administrator

The role of the EFB Administrator is a key factor in the running of the EFB system. He/she will need to receive appropriate training in the role and should have a good working knowledge of the proposed system hardware and operating system. The EFB system supplier should provide guidelines to clearly identify, which parts of the system can be accessed and modified by the EFB Administrator and which parts are only accessible by the supplier. It should also be clearly stated which changes and modifications may be further delegated by the EFB Administrator to maintenance and support staff. The EFB Administrator should establish procedures to ensure that these guidelines are strictly adhered to and that no unauthorised changes take place. The EFB Administrator will also be responsible for conducting audits and for ensuring that company procedures are complied with by all personnel. This should include systematic audits/checks against the procedures and random checks of reports to ensure that any detected errors are correctly followed up.

### 7.6 Flight Crew Training

Flight crew will need to be given specific training in the use of the EFB system before any approval is given. Training should include at least the following:

- An overview of the system architecture

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- 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 all of the system is not available
- Procedures for cross checking of data entry and computed information
- Phases of flight when the EFB system may and may not be used
- CRM and human factor considerations on the use of the EFB
- Additional training for new applications or changes to the hardware configuration

Consideration should also be given to the role that the EFB system plays in Operator Proficiency Checks as part of Recurrent training and checking.

**7.7 Operational Evaluation Test**

The object of the Operational Evaluation Test will be to verify that the above elements have been satisfied before final approval of the EFB in place of paper documentation.

**7.7.1 Initial Retention of Paper Back Up**

Where paper is initially retained as back up, the operational evaluation test will typically be conducted in two stages. The first stage should run in parallel with the equivalent paper format to verify the correctness and reliability of the system. This will normally be for a six-month period but may be varied at the discretion on the National Authority. The evaluation should include audits of the procedures used as well as checks on the accuracy of any computed data. On completion of the first stage a report should be sent to the National Authority who will then issue an approval for the use of the system in place of the paper format. As a precaution, the paper documentation must be retained during a second stage for use in the event of the EFB system not being available or any fault being detected with the system. When the National Authority is satisfied that the back-up procedures are sufficiently robust, approval may be given to allow removal of the paper documentation.

**7.7.2 Commencement of Operations without Paper Back Up**

Where the applicant / operator seeks credit to start of operations without paper back up the operational evaluation test will consist of the following elements:

- A detailed review of the operational risk analysis
- A simulator LOFT session to verify the use of the EFB under operational conditions including normal, abnormal and emergency conditions. Items such as a late runway change and diversion to an alternate should also be included. This should be conducted before any actual line flights, as the outcome may need a change to the flight crew training and/or administrative procedures.
- Observation by the authority of the initial line flights.

The authority must also be satisfied that operator will be able to continue to maintain the EFB to the required standard through the actions of the administrator and quality assurance system.

**7.8 Final Operational Report (Operational Compliance Summary)**

The operator should produce a final operational report, which summarises all activities conducted as demonstrated means of compliance, supporting the issue of an operational approval of the EFB system.
The report should include, but not be limited to, the following:

- EFB platform/hardware description
- Description of each software application to be included in the approval
- Risk analysis summary for each application and mitigation means put in place

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- Human factor assessment for the complete EFB system, human machine interface and all software applications
  - Pilot workload in both single-pilot and multi-crew flown aircraft
  - Size, resolution, and legibility of symbols and text
  - For navigation chart display: access to desired charts, access to information within a chart, grouping of information, general layout, orientation (e.g., track-up, north-up), depiction of scale information.
- Training
- EFB Administrator qualification

Once the Authority is satisfied that the EFB may be used in place of, or as an alternative to paper based information, it will issue an approval based on the submission described above.

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**Appendix A Examples of Type A Software Applications**

Based on FAA AC 120-76A. Differences from AC 120-76A are highlighted in bold text.

- Flight Crew Operations Manuals (FCOM) ***(Without contextual access based on sensed aircraft parameters)***
- Company Standard Operating Procedures (SOP)
- Airport diversion policy guidance, including a list of Special Designated Airports and/or approved airports with emergency medical service (EMS) support facilities
- Operations Specifications (OpSpecs)
- Cockpit observer briefing cards
- Airplane Flight Manuals (AFM) and Airplane Flight Manual Supplements (AFMS)
- Aircraft performance data (fixed, non-interactive material for planning purposes)
- Airport performance restrictions manual (such as a reference for takeoff and landing performance calculations)
- Maintenance manuals
- Aircraft maintenance reporting manuals
- Aircraft flight log and servicing records
- Autopilot approach and autoland records
- Flight Management System/Flight Management and Guidance System problem report forms
- Aircraft parts manuals
- Service bulletins/published Airworthiness Directives, etc.
- Air Transport Association (ATA) 100 format maintenance discrepancy write-up codes
- Required VHF Omni directional Range (VOR) check records
- Minimum Equipment Lists (MEL) ***(Without contextual access based on sensed aircraft parameters)***
- Configuration Deviation Lists (CDL)
- Federal, state, and airport-specific rules and regulations
- Airport/Facility Directory (A/FD) data (e.g., fuel availability, LAHSO distances for specific runway combinations, etc.)
- Noise abatement procedures for arriving and departing aircraft
- Published (graphical) pilot Notices to Airmen (NOTAM)
- International Operations Manuals, including regional supplementary information and International Civil Aviation Organization (ICAO) differences
- Aeronautical Information Publications (AIP)
-
- Oceanic navigation progress logs
- Pilot flight and duty-time logs
- Captain's report (i.e., captain's incident reporting form)
- Flight crew survey forms (various)
- Cabin Staff Manuals
- EMS reference library (for use during medical emergencies)
- Trip scheduling and bid lists
- Aircraft's captain's logs
- Aircraft's CAT II/CAT III landing records
- Antiterrorism profile data
- Hazardous Materials (HAZMAT)/oxidizer look-up tables
- Emergency Response Guidance for Aircraft Incidents Involving Dangerous Goods (ICAO Doc 9481-AN/928)
- Customs declaration
- Special reporting forms, such as Safety Reports, Airprox and Bird Strike reports.
- Incidents of interference to aircraft electronic equipment from devices carried aboard aircraft
- Current fuel prices at various airports
- Aircraft operating and information manuals
- Flight operations manuals including emergency procedures
- Airline policies and procedures manuals
- Aircraft Maintenance Manuals

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- Flight crew qualifications record keeping, including aircraft qualifications, CAT II/III, high minimums, landing currency, flight and duty time, etc.
- PIC currency requirements
- ***Weather information in a pre-composed format***

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**Appendix B Examples of Type B Software Applications**

Based on FAA AC 120-76A with additional notes highlighting potential need for airworthiness authority involvement during the operational approval process.

- Flight Crew Operations Manuals (FCOM) with contextual access based on sensed aircraft parameters
- Takeoff, en route, approach and landing, missed approach, go-around, etc., performance calculations. Data derived from algorithmic data or performance calculations based on software algorithms [1]
- Power settings for reduced thrust settings [1]
- Runway limiting performance calculations [1]
- Weight and balance calculations [1]
- Minimum Equipment Lists (MEL) with contextual access based on sensed aircraft parameters
- Panning, zooming, scrolling, and rotation for approach charts
- Pre-composed or dynamic interactive electronic aeronautical charts (e.g., en route, area, approach, and airport surface maps) including, centring and page turning but without display of aircraft/own-ship position [2]
- Electronic checklists, including normal, abnormal, and emergency (Without contextual access based on sensed aircraft parameters) [3]
- Applications that make use of the Internet and/or other aircraft operational communications (AAC) or company maintenance-specific data links to collect, process, and then disseminate data for uses such as spare parts and budget management, spares/inventory control, unscheduled maintenance scheduling, etc. (Maintenance discrepancy logs need to be downloaded into a permanent record at least weekly)
- Weather ***information with graphical interpretation***
- Cabin-mounted video and aircraft exterior surveillance camera displays

[1] Performance computation application including pre-composed and interactive data may be classified as a Type B, subject to consultation and agreement with the responsible airworthiness authority during the operational approval process. Otherwise, such applications should follow a normal airworthiness approval process.
[2] Dynamic interactive charts may need to follow a normal airworthiness approval process if functionality, accuracy, refresh rate and resolution enable to use this application as a navigation display.
[3] Electronic checklist may be classified as a Type B, subject to consultation and agreement with the responsible airworthiness authority during the operational approval process. Otherwise, such applications should follow a normal airworthiness approval process.

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**Appendix C Applications Ineligible for Type A or Type B EFB Classification**

When classifying the EFB Type, it is important that software applications are correctly classified and the appropriate level of airworthiness and operational assessment is clearly identified. Appendices A and B of this Leaflet list software applications which may be classified as either Type A or Type B and which may be approved through an operational approval process. The distinction between Type B and a software application that should undergo a normal airworthiness process is more difficult and will require negotiation between the applicant and the relevant JOEB Team / Central JAA or National Authority. The Notes within Appendix B are intended to highlight those applications that may require airworthiness review prior to operational approval.

The list below includes software applications that are considered by the JAA to be ineligible for classification as either Type A or B and will need to go through a full airworthiness approval process:

- Any application displaying information which may be directly used by the flight crew to control aircraft attitude, speed, altitude (e.g., PFD type of display)
- Any application displaying information which may be directly used by the flight crew to check or control the aircraft trajectory, either to follow the intended navigation route or to avoid adverse weather, obstacles or other traffic, in flight or on ground. Moving maps, or presentation of weather maps, terrain, other aircraft positions relative to ownship's position could fall into this category if accuracy, refresh rate and resolution are sufficient
- Any application displaying information which may be directly used by the flight crew to assess the status of aircraft critical and essential systems status, and/or to manage aircraft essential and critical systems following failure
- Any application enabling primary means of communications related to air traffic services, or whereby the flight path of the aircraft is authorised, directed or controlled
- Any application substituting or duplicating any certified avionics systems
- Applications which due to automatic interactions with other aircraft systems, displays and controls would raise significant human factors issues

Note 1: the wording "may directly be used by the flight crew" in the above criteria is intended to assess the potential use by the crew considering the functional capability of the application.
Note 2: applications covered by an airworthiness approval may contain user-modifiable software or data. The boundaries of the user-modifiable parts should be defined as part of the airworthiness approval.
Note 3: In case of doubt on the applicability of the above criteria, the application developer should contact the responsible authority and seek advice.

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**Appendix D Human Machine Interface Assessment and Human Factors Considerations**

**D1 General Principles**

This appendix provides guidance material for the assessment of the human machine interface associated with the EFB system. It provides general criteria that may be applied during assessments conducted during both the airworthiness and operational approvals and is restricted to human factors assessment techniques and means of compliance. The process for division of responsibilities and who does what, is contained within the main body of the Leaflet. Note: Where an assessment is conducted as part of an airworthiness approval i.e. for a Class 3 EFB system, JAA INT/POL/25/14 titled Human Factors Aspects of Flight Deck Design, should be applied.

**D2 Common Considerations**

**D2.1 Human Machine Interface**

The EFB system should provide a consistent and intuitive user interface, within and across the various hosted applications. This should include, but not be limited to, data entry methods, colour-coding philosophies, and symbology.

**D2.2 Legibility of Text**

Text displayed on the EFB should be legible to the typical user at the intended viewing distance(s) and under the full range of lighting conditions expected on a flight deck, including use in direct sunlight. Users should be able to adjust the screen brightness of an EFB independently of the brightness of other displays on the flight deck. In addition, when automatic brightness adjustment is incorporated, it should operate independently for each EFB in the flight deck. Buttons and labels should be adequately illuminated for night use. All controls must be properly labelled for their intended function. Consideration should be given to the long-term display degradation as a result of abrasion and aging.

**D2.3 Input Devices**

In choosing and designing input devices such as keyboards or cursor-control devices, applicants should consider the type of entry to be made and flight deck environmental factors, such as turbulence, that could affect the usability of that input device. Typically, the performance parameters of cursor control devices should be tailored for the intended application function as well as for the flight deck environment.

**D2.4 General EFB design guidelines**

**D2.4.1 Messages and the Use of Colours**. For any EFB system, EFB messages and reminders should meet the requirements in CS 23.1322 or 25.1322, as is appropriate for the intended aircraft. While the regulations refer to lights, the intent should be generalised to extend to the use of colours on displays and controls. That is, the colour “red” shall be used only to indicate a warning level condition. “Amber” shall be used to indicate a caution level condition. Any other colour may be used for items other than warnings or cautions, providing that the colours used, differ sufficiently from the colours prescribed to avoid possible confusion. EFB messages and reminders should be integrated with (or compatible with) presentation of other flight deck system alerts. EFB messages, both visual and auditory, should be inhibited during critical phases of flight. Flashing text or symbols should be avoided in any EFB application. Messages should be prioritised and the message prioritisation scheme evaluated and documented. Additionally, during critical phases of flight, required flight information should be continuously presented without un-commanded overlays, pop-ups, or pre-emptive messages, excepting those indicating the failure or degradation of the current EFB application. However, if there is a regulatory or Technical Standard Order (TSO) requirement that is in conflict with the recommendation above, those should have precedence.

**D2.4.2 System Error Messages.** If an application is fully or partially disabled, or is not visible or accessible to the user, it may be desirable to have a positive indication of its status available to the user upon request. Certain non-essential applications such as e-mail connectivity and administrative reports may require an error message when the user actually attempts to access the function rather than an immediate status annunciation when a failure occurs. EFB status and fault messages should be prioritised and the message prioritisation scheme evaluated and documented.

**D2.4.3 Data Entry Screening and Error Messages.** If user-entered data is not of the correct format or type needed by the application, the EFB should not accept the data. An error message should be provided that communicates which entry is suspect and specifies what type of data is expected. The EFB system should incorporate input error checking that detects input errors at the earliest possible point during entry, rather than on completion of a possibly lengthy invalid entry.

**D2.5 Error and Failure Modes**

**D2.5.1 Flight Crew Error.** The system should be designed to minimise the occurrence and effects of flight crew error and maximise the identification and resolution of errors. For example, terms for specific types of data or the format in which latitude/longitude is entered should be the same across systems. Data entry methods, colour-coding philosophies and symbology should be as consistent as possible across the various hosted EFB applications. These applications should also be compatible with other flight deck systems.

**D2.5.2 Identifying Failure Modes.** The EFB system should be capable of alerting the flight crew of probable EFB system failures.

**D2.6 Responsiveness of Application**

The system should provide feedback to the user when user input is accepted. If the system is busy with internal tasks that preclude immediate processing of user input (e.g., calculations, self-test, or data refresh), the EFB should display a “system busy” indicator (e.g., clock icon) to inform the user that the system is occupied and cannot process inputs immediately.

The timeliness of system response to user input should be consistent with an application’s intended function. The feedback and system response times should be predictable to avoid flight crew distractions and/or uncertainty.

**D2.7 Off-Screen Text and Content**

If the document segment is not visible in its entirety in the available display area, such as during “zoom” or “pan” operations, the existence of off-screen content should be clearly indicated in a consistent way. For some intended functions it may be unacceptable if certain portions of documents are not visible. This should be evaluated based on the application and intended operational function. If there is a cursor, it should be visible on the screen at all times while in use.

**D2.8 Active Regions**

Active regions are regions to which special user commands apply. The active region can be text, a graphic image, a window, frame, or other document object. These regions should be clearly indicated.

**D2.9 Managing Multiple Open Applications and Documents**

If the electronic document application supports multiple open documents, or the system allows multiple open applications, indication of which application and/or document is active should be continuously provided. The active document is the one that is currently displayed and responds to user actions. Under non-emergency, normal operations, the user should be able to select which of the open applications or documents is currently active. In addition, the user should be able to find which flight deck applications are running and switch to any one of these applications easily. When the user returns to an application that was running in the background, it should appear in the same state as when the user left that application – other than differences associated with the progress or completion of processing performed in the background.

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### D2.10 Flight Crew Workload

The positioning, of the EFB should not result in unacceptable flight crew workload. Complex, multi-step data entry tasks should be avoided during takeoff, landing, and other critical phases of flight. An evaluation of EFB intended functions should include a qualitative assessment of incremental pilot workload, as well as pilot system interfaces and their safety implications

### D3 Specific Application Considerations

### D3.1 Approach/Departure and Navigation Chart Display

The approach, departure, and navigation charts that are depicted should contain the information necessary, in appropriate form, to conduct the operation to at least a level of safety equivalent to that provided by paper charts. It is desirable that the EFB display size is at least as large as current paper approach charts and that the format be consistent with current paper charts. Alternate approach plate presentations may be acceptable, but will need to be evaluated and approved by the Authority for functionality and human factors.

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**Appendix E** **EFB classification matrix and derived certification and operational approval**

This appendix provides a matrix showing the relationship between the respective airworthiness and operational approval processes for all EFB Classes and Types.

| EFB Applications | Hardware Class | Airworthiness Involvement (Section 6) | Operational Involvement (Section 7) |
|---|---|---|---|
| Type A<br>Refer to<br>Appendix A | Class 1,2,3 | 1) Class 1: No<br>2) Class 2: Yes, for<br>• Mounting device<br>• Power<br>• Data Connectivity<br>3) Class 3: Yes for the EFB installation and human factor aspects<br>4) Type A: No | National Authority FOI:<br>• Risk Analysis<br>• Human Factor assessment<br>• Quality Assurance<br>• System Administration<br>• Crew Training<br>• Operational Evaluation Test<br>• Statement approval |
| Type B<br>Refer to<br>Appendix B | Class 1,2,3 | 1) Class 1: No<br>2) Class 2: Yes, for<br>• Mounting device<br>• Power<br>• Data Connectivity<br>3) Class 3: Yes for the EFB installation and human factor aspects<br>4) Type B: No* | JOEB or Central JAA who may delegate to a nominated National Authority FOI:<br>• Risk Analysis<br>• Human Factor assessment<br>• Quality Assurance<br>• System Administration<br>• Crew Training<br>• Operational Evaluation Test<br>• Final report |
| | | | |

* Subject to consultation and agreement with the responsible airworthiness authority during the operational approval process, see Appendix B.

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# Flight Crew Procedures Streamlined For Smoke/Fire/Fumes

**Based on accident/incident research and discussions during international meetings, a philosophy and a checklist template aim to standardize and optimize responses to nonalerted smoke/fire/fumes events.**

— FSF EDITORIAL STAFF

An international initiative to improve checklist procedures for airline pilots confronting smoke/fire/fumes has published two documents derived from conference calls, meetings and a final industry symposium March 1–2, 2005, in Atlanta, Georgia, U.S. The *Smoke/Fire/Fumes Philosophy and Definitions* and the *Smoke/Fire/Fumes Checklist Template* (page 33) specifically address flight crew responses to nonalerted smoke/fire/fumes events (i.e., events not annunciated to flight crews by aircraft detection systems). Flight Safety Foundation (FSF) in fall 2004 became the sponsor of this initiative.

These documents take into account a wide range of viewpoints, said James Burin, FSF director of technical programs, and they have been sent to the U.S. Federal Aviation Administration (FAA) for consideration during future revisions of Advisory Circular 120-80, *In-flight Fires* (see "FAA Will Consider Smoke/Fire/Fumes Recommendations," page 36). The following *Smoke/Fire/Fumes Philosophy and Definitions* document provides an overview of the issues addressed by the initiative and the consensus recommendations.

## Smoke/Fire/Fumes Philosophy and Definitions

This philosophy was derived by a collaborative group of industry specialists representing aircraft manufacturers, airlines/operators and professional pilot associations. The philosophy was used to construct the *Smoke/Fire/Fumes Checklist Template.*

## General

- The entire crew must be part of the solution.
- For any smoke event, time is critical.
- The *Smoke/Fire/Fumes Checklist Template:*
  - Addresses nonalerted smoke/fire/fumes events (smoke/fire/fumes event not annunciated to the flight crew by aircraft detection systems);
  - Does not replace alerted checklists (e.g., cargo smoke) or address multiple events;
  - Includes considerations to support decisions for immediate landing (an overweight landing, a tailwind landing, a ditching, a forced off-airport landing, etc.); and,
  - Systematically identifies and eliminates an unknown smoke/fire/fumes source.
- Checklist authors should consider a large font for legibility of checklist text in smoke conditions and when goggles are worn.
- At the beginning of a smoke/fire/fumes event, the crew should consider all of the following:
  - Protecting themselves (e.g., oxygen masks, smoke goggles);
  - Communication (crew, air traffic control);
  - Diversion; and,
  - Assessing the smoke/fire/fumes situation and available resources.

## Initial Steps for Source Elimination

- Assume pilots may not always be able to accurately identify the smoke source due to ambiguous cues, etc.
- Assume alerted-smoke-event checklists have been accomplished but the smoke's source may not have been eliminated.
- Rapid extinguishing/elimination of the source is the key to prevent escalation of the event.
- Manufacturer's initial steps that remove the most probable smoke/fumes sources and reduce risk must be immediately available to the crew. These steps should be determined by model-specific historical data or analysis.
- Initial steps:
  - Should be quick, simple and reversible;
  - Will not make the situation worse or inhibit further assessment of the situation; and,
  - Do not require analysis by the crew.

## Timing for Diversion/Landing

- Checklist authors should not design procedures that delay diversion.
- Crews should anticipate diversion as soon as a smoke/fire/fumes event occurs and should be reminded in the checklist to consider a diversion.
- After the initial steps, the checklist should direct diversion unless the smoke/fire/fumes source is positively identified, confirmed to be extinguished and smoke/fumes are dissipating.
- The crew should consider an immediate landing anytime the situation cannot be controlled.

## Smoke or Fumes Removal

- This decision must be made based upon the threat being presented to the passengers or crew.
- Accomplish *Smoke or Fumes Removal Checklist* procedures only after the fire has been extinguished or if the smoke/fumes present the greatest threat.
- Smoke/fumes removal steps should be identified clearly as removal steps and the checklist should be easily accessible (e.g., modular, shaded, separate, standalone, etc.).

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| Smoke/Fire/Fumes Checklist Template | |
|---|---|
| **Step** | **Action** |
| **1** | Diversion may be required. |
| **2** | Oxygen masks (if required) ........ On, 100% |
| **3** | Smoke goggles (if required) ........ On |
| **4** | Crew and cabin communications ........ Establish |
| **5** | Manufacturer's initial steps[1] ........ Accomplish |
| Any time smoke or fumes become the greatest threat, accomplish *Smoke or Fumes Removal Checklist*. | |
| **6** | Source is immediately obvious and can be extinguished quickly:<br>• If yes, go to **Step 7**.<br>• If no, go to **Step 9**. |
| **7** | Extinguish the source.<br>If possible, remove power from affected equipment by switch or circuit breaker on the flight deck or in the cabin. |
| **8** | Source is visually confirmed to be extinguished:<br>• If yes, consider reversing manufacturer's initial steps.<br>Go to **Step 17**.<br>• If no, go to **Step 9**. |
| **9** | Remaining minimal essential manufacturer's action steps ........ Accomplish<br>[These are steps that do not meet the "initial steps" criteria but are probable sources.][2] |
| **10** | Initiate a diversion to the nearest suitable airport while continuing the checklist. |
| **Warning:** If the smoke/fire/fumes situation becomes unmanageable, consider an immediate landing. | |
| **11** | Landing is imminent:<br>• If yes, go to **Step 16**.<br>• If no, go to **Step 12**. |
| **12** | XX system actions[3] ........ Accomplish<br>[Further actions to control/extinguish source.]<br>If dissipating, go to **Step 16**. |
| **13** | YY system actions ........ Accomplish<br>[Further actions to control/extinguish source.]<br>If dissipating, go to **Step 16**. |
| **14** | ZZ system actions ........ Accomplish<br>[Further actions to control/extinguish source.]<br>If dissipating, go to **Step 16**. |
| **15** | Smoke/fire/fumes continue after all system-related steps are accomplished:<br>Consider landing immediately.<br>Go to **Step 16**. |
| **16** | Review **Operational Considerations**. |
| **17** | Accomplish *Smoke or Fumes Removal Checklist*, if required. |
| **18** | Checklist complete. |

**Operational Considerations**

[These items appear after "checklist complete." This area should be used to list operational considerations, such as an overweight landing, a tailwind landing, a ditching, a forced off-airport landing, etc.]

**Notes**

1. These aircraft-specific steps will be developed and inserted by the aircraft manufacturer.
2. Bracketed text contains instructions/explanations for the checklist author.
3. "XX," "YY" and "ZZ" are placeholders for the environmental control system, electrical system, in-flight entertainment system and/or any other systems identified by the aircraft manufacturer.

- The crew may need to be reminded to remove smoke/fumes.

- The crew should be directed to return to the *Smoke/Fire/Fumes Checklist* after smoke/fumes removal if the *Smoke/Fire/Fumes Checklist* was not completed.

### Additional Steps for Source Elimination

- Additional steps aimed at source identification and elimination:

  – Are subsequent to the manufacturer's initial steps and the diversion decision;

  – Are accomplished as time and conditions permit, and should not delay landing; and,

  – Are based on model-specific historical data or analysis.

- The crew needs checklist guidance to systematically isolate an unknown smoke/fire/fumes source.

### Definitions

**Confirmed to be extinguished:** The source is visually confirmed to be extinguished. (You can "put your tongue on it.")

**Continued flight:** Once a fire or a concentration of smoke/fumes is detected, continuing the flight to the planned destination is not recommended unless the source of the smoke/fire/fumes is confirmed to be extinguished and the smoke/fumes are dissipating.

**Diversion may be required:** Establishes the mindset that a diversion may be required.

**Land at the nearest suitable airport:** Commence diversion to the nearest suitable airport. The captain also should evaluate the risk presented by conditions that may affect safety of the passengers associated with the approach, landing and post-landing.

**Landing is imminent:** The airplane is close enough to landing that the remaining time must be used to prepare for approach and landing. Accomplishing further smoke/fire/fumes-identification steps would delay landing.

**Land immediately:** Proceed immediately to the nearest landing site. Conditions have deteriorated and risks associated with the approach, landing or post-landing are exceeded by the risk of the on-board situation. "Immediate landing" implies immediate diversion to a landing on a runway; however, smoke/fire/fumes scenarios may be severe enough that the captain should consider an overweight landing, a tailwind landing, a ditching, a forced off-airport landing, etc.

**Crew:** For the purposes of this document, the term "crew" includes all cabin crewmembers and flight crewmembers.■

## Participants in Smoke/Fire/Fumes Initiative

The following volunteers participated in the smoke/fire/fumes initiative:

### Steering Committee

Capt. H.G. (Boomer) Bombardi
Safety Representative,
International Federation of Air Line Pilots' Associations (IFALPA)

James Burin
Director of Technical Programs,
Flight Safety Foundation

Mike Galusha
Manager–Operational Manuals,
Flight Operations,
Delta Air Lines

Capt. Jerry Gossner
Fleet Technical Captain Boeing 757/767,
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Peter Harrison
Section Chief, Flight Crew Manuals,
Airworthiness Engineering and Product Development, Bombardier Aerospace

Ronald Haughton
Senior Pilot, Engineering, Flight Operations,
Canadair, Bombardier Aerospace

Barbara Holder, Ph.D.
Human Factors Specialist, Aviation System Safety, Commercial Airplanes,
The Boeing Co.

William McKenzie
Manager, Flight Crew Procedures;
Training, Technical and Standards; Flight Crew Operations; The Boeing Co.

Capt. Thomas Phillips
Chairman, Aircraft Design and Operations Group, and Accident Investigator, IFALPA

Capt. Klaus Walendy
Senior Director Training Policy, Training and Flight Operations Support and Services, Airbus

Capt. Dave Young
General Manager Fleet Programs and Technical, Delta Air Lines

## Other Participants

Wolfgang Absmeier
Experimental Test Pilot, Engineering Flight Operations, Airbus

Capt. Jeff Benedet
CRJ Customer Liaison Pilot, Training Centre–Montréal Regional Aircraft, Bombardier Aerospace

Dave Blake
Aerospace Engineer, William J. Hughes Technical Center, U.S. Federal Aviation Administration (FAA)

Capt. Brian Boucher
MEC Vice-Chair, Air Canada Pilots Association

Barbara Burian, Ph.D.
Senior Research Associate, Ames Research Center, U.S. National Aeronautics and Space Administration (NASA)

Capt. Bruce Campbell
Flight Manager, CRJ Montréal, Air Canada

Chiy Nei-Wei (Larry)
Assistant General Manager, China Airlines

Capt. John Creighton
Chief Pilot; Training, Technical and Standards; The Boeing Co.

Capt. Rich Cunningham
Manager Flight Safety Programs, American Airlines

Daryl Deacon
Flight Manager – Embraer 145, British Airways CitiExpress

Capt. Henry Defalque
Assistant Director, Flight Operations Technical Operations, International Air Transport Association (IATA)

Asaf Degani, Ph.D.
Senior Scientist, NASA Ames Research Center

Capt. T.G. (Tim) Dineen
Chief Test Pilot, Experimental Flight Operations, Long Beach Division, The Boeing Co.

Katherine Feeley
Flight Attendant, Dassault Falcon Jet

Charles (Sam) Gemar
Chief, Flight Test Operations and Safety, Bombardier Aerospace

Capt. Robert Georges
Air Line Pilots Association, International

Vic Gerden
Senior Adviser, National/International Investigations, Transportation Safety Board of Canada

Capt. Richard Gilbert
Assistant Chief Pilot A319/A320 Fleet, United Airlines

Paul Hansen
Pilot/Safety Manager, Dassault Falcon Jet

Daniel Jenkins
Aviation Safety Inspector–Operations, Air Transportation Division, FAA

James Kaiser
Manager, Flight Operations Quality Control, American Airlines

Michel Kassiadis
Instructor Pilot, Embraer (Empresa Brasileira de Aeronáutica)

Peter Keys
Aviation Safety Inspector, Air Carrier, FAA

Capt. Richard Lenz
Flight Safety Officer, Lufthansa German Airlines

Edward Lyons
Managing Director, Flight Safety and Regulatory Compliance, FedEx Express Flight Safety

Mike Quinn
Airworthiness – Airplane Flight Manuals, Bombardier Aerospace

Hélène Rebel
Group Manager A330/A340 Operational Standards, Flight Operations Support, Airbus

Capt. Frank Santoni
777 Chief Pilot, Flight Crew Operations, The Boeing Co.

Juerg Schmid
Vice President Safety, Swiss International Air Lines

Harold (Chip) Sieglinger
Chief Pilot, Flight Technical Services, Long Beach Division, The Boeing Co.

Capt. Brian Smyth
Standards Pilot A320, Air Canada

David Tew
Air Safety Investigator, U.S. National Transportation Safety Board

Domingos Trece
Operations Engineer, Embraer

Craig Tylski
Principal Engineering Test Pilot, Bombardier Aerospace

Capt. Donald Van Dyke
Former Director, Operations, IATA

Xavier Villain
Flight Operations Engineer, Flight Operations Support, Airbus

Richard Walker
Engineering Test Pilot, Transport Canada

Rod Young
Flight Manager, Technical 757/767/777, Flight Operations, British Airways ■

# FAA Will Consider Smoke/Fire/Fumes Recommendations

After participating in the March 2005 smoke/fire/fumes symposium sponsored by Flight Safety Foundation, Daniel Jenkins, aviation safety inspector–operations, Air Transportation Division, U.S. Federal Aviation Administration (FAA), said that FAA expects the *Smoke/Fire/Fumes Philosophy and Definitions* (page 31) and the *Smoke/Fire/Fumes Checklist Template* (page 33) to make a significant contribution to the agency's ongoing work on related advisory material and U.S. Federal Aviation Regulations.[1] Jenkins led the FAA team that issued Advisory Circular (AC) 120-80, *In-flight Fires*, in 2004. The AC discusses the risks of in-flight fires with emphasis on hidden fires that may not be visible or easily accessed by the crew; the importance of immediate and aggressive response by crewmembers; the effectiveness of Halon extinguishing agents; methods of extinguishing readily accessible fires; related training issues; and results of related research.

"Participants did a very good job of breaking down elements such as identifying when a flight crew would need to land immediately vs. land at the nearest suitable airport," he said. "Their recommendations will be invaluable in enhancing the next version of AC 120-80 by enabling the subject matter to be further defined and refined, and by potentially adding information on issues that were not previously addressed. I was encouraged to learn that the symposium participants were looking into these issues. Their efforts to develop a philosophy and a standardized template that could be used by manufacturers and air carriers to develop their own checklists is a very good method. It was encouraging to see that manufacturers, air carriers and regulators came together to address this important issue. The result will enable the template to be used as a guide for checklist development as they put together their programs for nonalerted in-flight fires."

Investigation of the 1998 Swissair Flight 111 accident[2] by the Transportation Safety Board of Canada prompted the U.S. National Transportation Safety Board (NTSB) and FAA to provide additional guidance to aircraft crews about how to handle emergency scenarios involving hidden in-flight fires, Jenkins said.

"Before AC 120-80 was issued, our guidance had not specifically focused on nonalerted in-flight cabin fires — fires for which there is no automatic warning system to provide an alert to the crew," he said. "These fires typically occur in the aircraft's sidewall, overhead areas or other inaccessible areas of the cabin. Smoke/fire/fumes in this context has been a difficult issue to address partly because it is driven by the aircraft configuration, how a particular operator uses the aircraft and the purpose of the aircraft relative to the operator's use."

Source identification, access to the fire and immediate landing become the overriding concerns when a hidden fire occurs.

"Source identification is critical and may be as simple as locating a hot spot on the aircraft's interior or the presence of smoke within the cabin," Jenkins said. "Nevertheless, crewmembers may not see the smoke because environmental control systems exchange air very rapidly during flight. Their sense of smell may become the primary detector. Access also can be very difficult because airframes typically are not designed with fire fighting access points, except for certain controlled areas. For different aircraft, there are different methods of accessing hidden areas and crews must be aggressive and creative to gain access to the fire. Each operator should understand the configuration design of its aircraft and provide information about access to their crews."

Development of the template for checklist authors at aircraft manufacturers and air carriers complements concepts of cabin crew training that were addressed in AC 120-80, he said.

"How a template eventually will be integrated into a U.S. air carrier's system will be left up to the particular carrier," Jenkins said.

FAA continues to encourage input to the AC from the industry, individuals and other regulatory bodies, he said. Future revisions to AC 120-80 will be subject to the normal due-diligence processes. ■

— FSF Editorial Staff

## Notes

1. Jenkins, Daniel. Interview by Rosenkrans, Wayne. Herndon, Virginia, U.S. March 11, 2005. Flight Safety Foundation, Alexandria, Virginia, U.S.

2. Transportation Safety Board of Canada (TSB). Aviation Investigation Report no. A98H0003, *In-flight Fire Leading to Collision with Water, Swissair Transport Limited, McDonnell Douglas MD-11, HB-IWF, Peggy's Cove, Nova Scotia 5 nm SW, 2 September 1998*. At 2018 local time on Sept. 2, 1998, Swissair Flight 111 struck the ocean about 5.0 nautical miles (9.3 kilometers) southwest of Peggy's Cove, Nova Scotia, Canada, while the crew was diverting to Halifax International Airport, Nova Scotia, after an abnormal odor, smoke and fire progressively were detected in the cockpit. The 215 passengers and 14 crewmembers were killed; the aircraft was destroyed. TSB, in its final report, said that causes and contributing factors included inadequate aircraft certification standards for material flammability; flammable cover material on acoustic insulation blankets; flame-propagation characteristics of thermal acoustic insulation cover materials; silicone elastomeric end caps, hook-and-loop fasteners, foams, adhesives and thermal acoustic insulation splicing tapes that contributed to the propagation and intensity of the in-flight fire; and circuit breakers, similar to those in general aircraft use, that were not capable of protecting against all types of wire arcing events. "The fire most likely started from a wire arcing event," TSB said.

# New Zealand Accident Rates for Larger Airplanes, Helicopters Better Than Regulatory-agency Targets

**Airplanes carrying revenue passengers and freight showed decreasing long-term accident rates. The improvement was most pronounced in airplanes with maximum takeoff weights between 5,670 kilograms (12,500 pounds) and 13,608 kilograms (30,000 pounds). In year-to-year comparisons of corresponding six-month periods, the number of incidents involving airplanes carrying revenue passengers and freight increased.**

— FSF EDITORIAL STAFF

Between the third quarter of 2000 and the first quarter of 2005, the New Zealand civil aviation accident rate (based on a 10-year moving average) decreased significantly for airplanes with maximum takeoff weights between 5,670 kilograms and 13,608 kilograms (12,500 pounds and 30,000 pounds) carrying revenue passengers and freight (Figure 1, page 38).[1, 2] The rate for the period was below the 2005 target, set by the Civil Aviation Authority of New Zealand (CAA), of 0.5 accidents per 100,000 flight hours. The equivalent accident rate for airplanes 13,608 kilograms and greater decreased slightly for the period and was below the CAA 2005 target of 0.4 accidents per 100,000 flight hours (Figure 2, page 38).

The accident rate for helicopters carrying revenue passengers and freight (based on a 12-month moving average) also decreased (Figure 3, page 39). The rate was below the CAA 2005 target of 4.0 accidents per 100,000 flight hours.

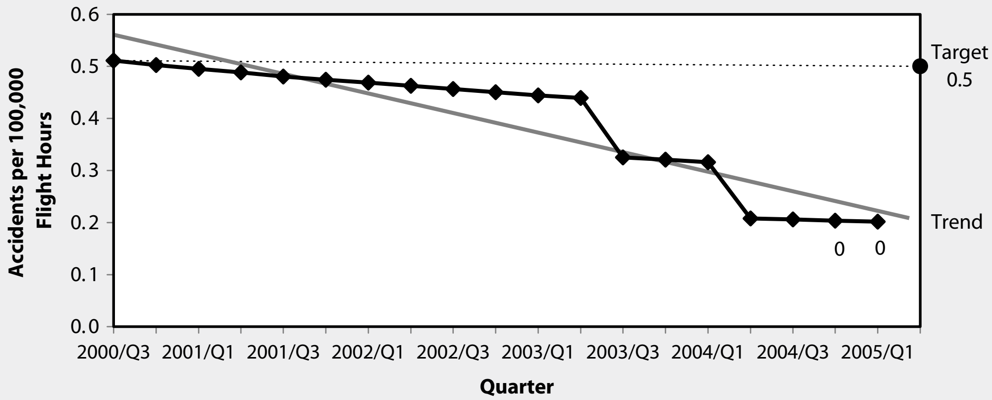
For the three-year period April 1, 2002, through March 31, 2005, incident rates (based on a 12-month moving average) involving airplanes carrying revenue passengers and freight 13,608 kilograms and greater and those between 5,670 kilograms and 13,608 kilograms are shown in Figure 4 (page 39).[3] Equivalent data for helicopters are shown in Figure 5 (page 40).

In successive-year six-month periods (Jan. 1, 2003, to June 30, 2003, compared with Jan. 1, 2004, to June 30, 2004), the number of incidents in both airplane categories rose, while the number of helicopter incidents fell slightly (Table 1, page 40).

Incidents in the 2003 and 2004 six-month periods were classified according to severity. There were no critical incidents[4] in either airplane category in either six-month period. Major incidents[5] decreased between the 2003 six-month period and the 2004 six-month period in both airplane categories. Minor incidents[6] increased between the six-month periods

**Figure 1**

**Accident Rate (10-year Moving Average), Airplanes 5,670 Kilograms to 13,608 Kilograms (5,670 Pounds to 30,000 Pounds), New Zealand, July 1, 2000–March 31, 2005**




Note:

Data are for airplanes carrying revenue passengers and freight.

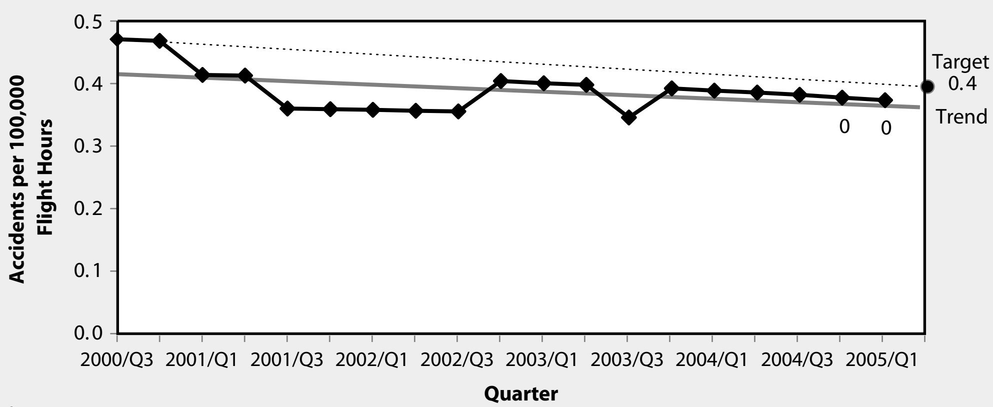
Zeros in the two most recent quarters indicate that there were no accidents in this category in those quarters.

Target is set by the Civil Aviation Authority of New Zealand for 2005.

Source: Civil Aviation Authority of New Zealand

**Figure 2**

**Accident Rate (10-year Moving Average), Airplanes 13,608 Kilograms (30,000 Pounds) And Greater, New Zealand, July 1, 2000–March 31, 2005**




Note:

Data are for airplanes carrying revenue passengers and freight.

Zeros in the two most recent quarters indicate that there were no accidents in this category in those quarters.

Target is set by the Civil Aviation Authority of New Zealand for 2005.

Source: Civil Aviation Authority of New Zealand

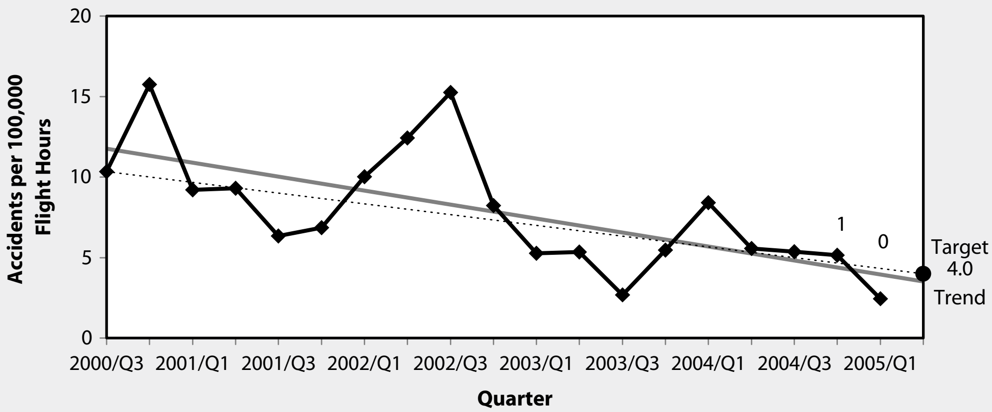
in both airplane categories. (CAA did not break out data for helicopter-incident severity from a category that also included incidents involving airplanes less than 5,670 kilograms and sport aircraft.)

Incidents in the successive-year six-month periods were classified by type. The two most common types were airspace incidents[7] and defect incidents.[8]

For airplanes 13,608 kilograms and greater, the number of airspace incidents increased between the 2003 six-month period and the 2004 six-month period (Table 2, page 41). Airplanes between 5,670

**Figure 3**

**Accident Rate (12-month Moving Average), Helicopters, New Zealand, July 1, 2000–March 31, 2005**




Note:

Data are for helicopters carrying revenue passengers and freight.

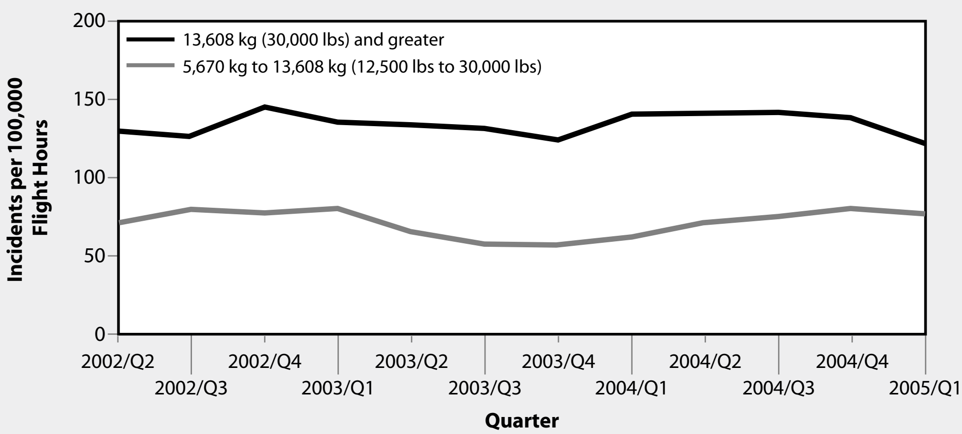
Numbers in the two most recent quarters indicate the numbers of accidents in this category in those quarters.

Target is set by the Civil Aviation Authority of New Zealand for 2005.

Source: Civil Aviation Authority of New Zealand

**Figure 4**

**Incident Rates (12-month Moving Average), Airplanes 5,670 Kilograms (12,500 Pounds) And Greater, New Zealand, April 1, 2002–March 31, 2005**




Note:

An *incident* is defined as any occurrence, other than an accident, that is associated with the operation of an aircraft and affects or could affect the safety of operation.

Data exclude incidents involving sport airplanes.

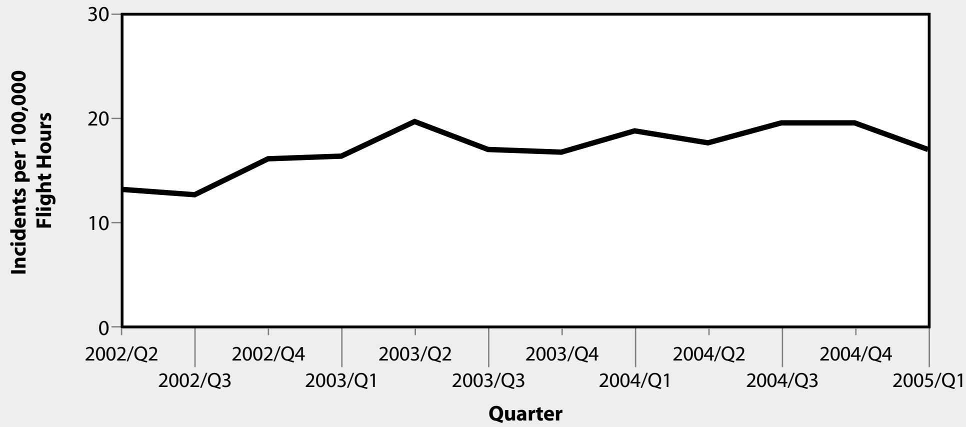
Source: Civil Aviation Authority of New Zealand

kilograms and 13,608 kilograms had fewer airspace incidents in the more recent period. Airspace incidents for helicopters increased.

For airplanes 13,608 kilograms and greater, the number of airspace incidents classified as major remained steady from the 2003 six-month period to the 2004 six-month period, while airspace incidents classified as minor increased. For airplanes between 5,670 kilograms and 13,608 kilograms, airspace incidents classified both as major and as minor decreased.

**Figure 5**

**Incident Rate (12-month Moving Average), Helicopters, New Zealand, April 1, 2002–March 31, 2005**




Note:

An *incident* is defined as any occurrence, other than an accident, that is associated with the operation of an aircraft and affects or could affect the safety of operation.

Source: Civil Aviation Authority of New Zealand

**Table 1**

**Six-month Comparison, Aircraft Incidents, New Zealand, 2003–2004**

| Aircraft Group (Maximum Takeoff Weight) | Number of Incidents: Jan. 1, 2003 to June 30, 2003 | Number of Incidents: Jan. 1, 2004 to June 30, 2004 | Change in Incidents: Number | Change in Incidents: Percentage |
|---|---|---|---|---|
| 13,608 kilograms/30,000 pounds or greater | 120 | 178 | +58 | +48 |
| 5,670 kilograms/12,500 pounds to 13,608 kilograms | 29 | 47 | +18 | +62 |
| Helicopters | 14 | 13 | –1 | –7 |
| **Total** | **163** | **238** | **+75** | **+46** |

Note:

An *incident* is defined as any occurrence, other than an accident, that is associated with the operation of an aircraft and affects or could affect the safety of operation.

Source: Civil Aviation Authority of New Zealand

Defect incidents increased in both airplane categories and for helicopters in the 2004 six-month period, with helicopters showing the highest percentage increase (Table 3, page 41). For airplanes 13,608 kilograms and greater, defect incidents classified as major and those classified as minor both increased between periods. Airplanes between 5,670 kilograms and 13,608 kilograms had fewer defect incidents classified as major and more defect incidents classified as minor in the 2004 period.

The data are published on the Internet at <www.caa.govt.nz>. ■

## Notes

1. A moving average is an average that is recomputed periodically in a time series by including the most recent data and eliminating the oldest data.
2. The report said, "The actual aircraft groups used to derive data in this report, although reported to the nearest kilogram, have been based on the imperial measures used in the United States design requirements, which are the basis for the certification of most aircraft." To group together aircraft of similar complexity and associated operational factors, the nominal values of 13,600 kilograms for 30,000 pounds and 5,700 kilograms for 12,500 pounds (rather than

**Table 2**
**Six-month Comparison, Airspace Incidents, New Zealand, 2003–2004**

| Aircraft Group (Maximum Takeoff Weight) | Number of Incidents | | Change in Incidents | |
|---|---|---|---|---|
| | Jan. 1, 2003 to June 30, 2003 | Jan. 1, 2004 to June 30, 2004 | Number | Percentage |
| 13,608 kilograms/30,000 pounds or greater | 39 | 47 | +8 | +21 |
| 5,670 kilograms/12,500 pounds to 13,608 kilograms | 30 | 25 | –5 | –17 |
| Helicopters | 15 | 17 | +2 | +13 |
| **Total** | **84** | **89** | **+5** | **+6** |

Note:

An *airspace incident* is defined as an incident involving deviation from, or shortcomings of, the procedures or rules for (1) avoiding collisions between aircraft or (2) avoiding collisions between aircraft and other obstacles when an aircraft is being provided with an air traffic service.

Source: Civil Aviation Authority of New Zealand

**Table 3**
**Six-month Comparison, Defect Incidents, New Zealand, 2003–2004**

| Aircraft Group (Maximum Takeoff Weight) | Number of Incidents | | Change in Incidents | |
|---|---|---|---|---|
| | Jan. 1, 2003 to June 30, 2003 | Jan. 1, 2004 to June 30, 2004 | Number | Percentage |
| 13,608 kilograms/30,000 pounds or greater | 199 | 283 | +84 | +42 |
| 5,670 kilograms/12,500 pounds to 13,608 kilograms | 29 | 38 | +9 | +31 |
| Helicopters | 38 | 57 | +19 | +50 |
| **Total** | **266** | **378** | **+112** | **+42** |

Note:

A *defect incident* is defined as an incident that involves failure or malfunction of an aircraft or aircraft component, whether found in flight or on the ground.

Source: Civil Aviation Authority of New Zealand

13,608 kilograms and 5,670 kilograms respectively) better represent logical dividing points, the report said.

3. An *incident* is defined by the Civil Aviation Authority of New Zealand (CAA) as any occurrence, other than an accident, that is associated with the operation of an aircraft and affects or could affect the safety of operation.

4. A *critical incident* is defined by CAA as an occurrence or deficiency that caused, or on its own had the potential to cause, loss of life or limb.

5. A *major incident* is defined by CAA as an occurrence or deficiency involving a major system that caused, or had the potential to cause, significant problems to the function or effectiveness of that system.

6. A *minor incident* is defined by CAA as an isolated occurrence or deficiency not indicative of a significant system problem.

7. An *airspace incident* is defined by CAA as an incident involving deviation from, or shortcomings of, the procedures or rules for (1) avoiding collisions between aircraft or (2) avoiding collisions between aircraft and other obstacles when an aircraft is being provided with an air traffic service.

8. A *defect incident* is defined by CAA as an incident that involves failure or malfunction of an aircraft or aircraft component, whether found in flight or on the ground.

# Barriers Help Contain Multiple-failure Accidents

**Barriers are critical design elements for safety because they offer double benefits, the author says. They can prevent a failure or can lessen the consequences if a failure occurs. Moreover, they offer some protection against multiple failures that are difficult to anticipate because there are so many potential combinations.**

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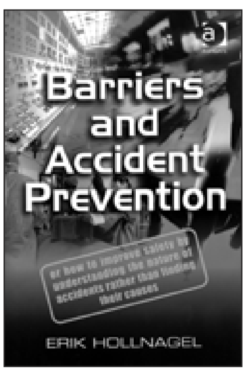



## Books

***Barriers and Accident Prevention.*** Hollnagel, Erik. Aldershot, England: Ashgate Publishing, 2004. 242 pp. Tables, figures, bibliography, indexes.

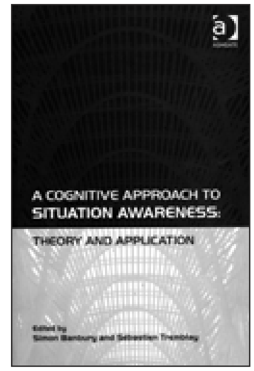
The book examines many theoretical models of accident causation, but emphasizes ideas that the author believes will be useful for readers who are in a position to change operating practices.

"A barrier is, generally speaking, an obstacle, an obstruction or a hindrance that may either (1) prevent an event from taking place or (2) thwart or lessen the impact of the consequences if it happens nonetheless," says the author. "In the former case, the purpose of the barrier is to make it impossible for a specific action or event to occur. In the latter case, the barrier serves, for instance, to slow down uncontrolled releases of matter and energy, to limit the reach of the consequences or to weaken them in other ways."

Accidents rarely happen today because of a single failure in advanced technological systems, the author says; engineers and designers have learned to guard against the failure of individual devices or systems.

"This, however, does not rule out accidents that happen when two or more failures occur together, as when a simple performance failure combines with a weakened or dysfunctional barrier," the author says. "Such combinations are much harder to predict than single failures, and therefore also harder to prevent. Since the number of combinations of single failures can be exceedingly large, it is usually futile to prevent multiple-failure accidents by a strict elimination of individual causes. A much more efficient solution is to make use of barriers, since the effectiveness of a barrier does not depend on knowing the precise cause of the event."

The book discusses in detail the uses and potential drawbacks of various kinds of barrier systems: physical or material (e.g., walls, fences, containers and firewalls); functional (e.g., a physical lock that requires a key or a logical lock that requires some kind of password or identification); symbolic (e.g., warning lights or warning notices); and incorporeal (laws, rules, guidelines and safety cultures).



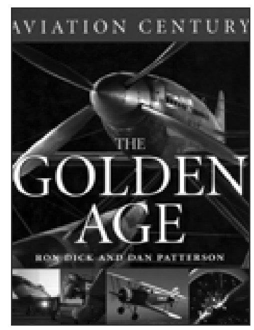

***A Cognitive Approach to Situation Awareness: Theory and Application.*** Banbury, Simon; Tremblay, Sébastien (editors). Aldershot, England: Ashgate Publishing, 2004. 371 pp. Tables, figures, references, indexes.

"The major impetus of research has been on the development of techniques to measure SA [situation awareness], at the expense of a more rigorous understanding of why SA varies under certain psychological and environmental conditions," say the editors. The book is a collection of 17 papers describing various aspects of the theory and application from a cognitive perspective — that is, related to perception, learning and knowledge.

Two papers will be of particular interest to researchers in aviation psychology.

"Individual Differences in Situation Awareness for Transportation Tasks," by Leo Gugerty, Johnell O. Brooks and Craig A. Treadaway, focuses on how individual differences in perceptual abilities and cognitive abilities are related to the ability to perform navigation and maneuvering. Experimental studies in both tasks are described.

"Effects of Situation Awareness Training on Flight Crew Performance," by Hans-Jürgen Hörmann and colleagues, reports the results of a study involving 32 airline pilots to evaluate the effects of SA training on measures of pilots' behavior, skills and attitudes toward SA. "The results provided significant empirical evidence for the effectiveness of the ESSAI methods to train flight crews' SA and TM [threat management]," the authors say. "Positive training effects could be demonstrated on flight crew performance in specifically designed assessment scenarios." (ESSAI — Enhanced Safety Through Situation Awareness Integration — is a European research consortium that has developed a comprehensive training program for SA and TM.)




***Aviation Century: The Golden Age.*** Dick, Ron; Patterson, Dan. Erin, Ontario, Canada: Boston Mills Press, 2004. 288 pp. Photographs (color and black-and-white), bibliography, index.

Like its predecessor in the Aviation Century series, *World War II* (*Flight Safety Digest*, April 2005, p. 23), this volume combines detailed text with historical photographs and modern photographs by Dan Patterson to illuminate an earlier era of aviation. "The Golden Age" of the book's title was the 1920s and 1930s.

Much of civilian aviation early in this period was show business, conducted by stunt pilots known as "barnstormers." Nevertheless, there were pilots who continued to extend aviation's possibilities.

Charles Lindbergh's solo trans-Atlantic flight in 1927 especially caught the public imagination, yet there were other, equally daring pioneers: John Alcock and Arthur Whitten-Brown, two British pilots who were the first to fly nonstop across the Atlantic from Newfoundland, Canada, to Northern Ireland in 1919; Bert Hinkler, an Australian who made the first solo flight from England to Australia in 1928; and Amy Johnson, who, with 85 flight hours of single-pilot experience, flew solo from Croydon, England, to Port Darwin, Australia, in a de Havilland Gipsy Moth. (Johnson said of her feat of flying halfway around the world in an airplane powered by a 100-horsepower engine, "The prospect did not frighten me, because I was so appallingly ignorant that I never realized in the least what I had taken on.")

Military aviation also eventually resumed its progress, despite the frequent skepticism of high-ranking officers and, in Germany, in violation of the arms-limitation provisions of the Treaty of Versailles. By the time of the Spanish Civil War (beginning in 1936), dive bombing was practiced in earnest, monoplanes were beginning to replace biplanes and German transports carried 14,000 Spanish Nationalist troops and their equipment to Spain from North Africa.

"This volume of Aviation Century tells a tale of romance and adventure, of daring and bravado," says the author. "Aviators shrink the world and prepare for war on a global scale. The stories of their achievements become the stuff of legend, and their machines are revered as artifacts of a Golden Age."

## Reports

***Report on the Testing and Systematic Evaluation of the airEXODUS Aircraft Evacuation Model.*** U.K. Civil Aviation Authority (CAA) Safety Regulation Group (SRG). CAA Paper 2004/05. April 2005. 95 pp. Tables, appendixes. Available on the Internet at <www.caa.co.uk> or from Documedia.*

"Before computer models can reliably be used for certification applications, they must undergo a range of validation demonstrations," says the report. "While validation will never prove a model correct, confidence in the model's predictive capabilities will be improved the more often it is shown to produce reliable predictions." This report describes the testing and evaluation of the ability of the airEXODUS aircraft-evacuation model to reproduce the certification-evacuation trials of six aircraft.

A major aim of the study was to show that airEXODUS can predict small differences in the outcomes of evacuation trials among derivative aircraft belonging to a single aircraft family. Therefore, for the testing and evaluation, derivative aircraft (both wide-body and narrow-body) were selected. The aircraft included five different types of exits.

The airEXODUS model uses 90-second-evacuation certification data to specify model parameters. "In the work presented here, the most important parameter is the passenger-exit-delay time," says the report. "This time represents the two stages of the exiting process, the exit-hesitation time and the exit-negotiation time [the time to pass through the exit]. … Another key parameter in airEXODUS is the exit-ready time. This attribute represents the time required by a crewmember or passenger to render the exit escape system ready for use."

Data derived from video recordings of each exit on each aircraft in actual evacuation trials were compared with airEXODUS simulations. Each airEXODUS simulation was repeated 1,000 times to generate a distribution of results representing minor variations to be expected among trials. "Using the mean of the airEXODUS-generated total-evacuation-time distribution for each aircraft and the single time achieved by the aircraft in each of the [actual] trials to represent the typical evacuation performance, airEXODUS is capable of predicting the total evacuation time to within 5.3 percent or 3.8 seconds on average," says the report.

The evaluation also indicated that the current certification process is unable to "meaningfully rank aircraft-evacuation performance" on the basis of a single trial, because only repeated evacuation trials — or computer simulation — can provide a total-evacuation-time probability distribution, the report says.

"The success of airEXODUS in predicting the outcome of previous 90-second certification trials is a compelling argument of the suitability of this model for evacuation-certification applications — at least for derivative aircraft," says the report. "For aircraft involving truly 'new' features, it is expected that evacuation models in conjunction with component testing of the new feature will be necessary."

***Complexity and Automation Displays of Air Traffic Control: Literature Review and Analysis.*** U.S. Federal Aviation Administration (FAA) Office of Aerospace Medicine. DOT/FAA/AM-05/4. Final report. April 2005. Xing, Jing; Manning, Carol A. Figure, tables, references. 24 pp. Available on the Internet at <www.cami.jccbi.gov> or through National Technical Information Service (NTIS).**

In the dynamic air traffic control (ATC) environment, controllers must integrate and manage large volumes of information from multiple sources without compromising or overwhelming their cognitive capacities. Automation tools and automation displays intended to reduce workload can also introduce additional complexity to ATC task management.

This study and literature review was designed to develop objective measures of the complexity of ATC displays that are composed mainly of graphical symbols and text. "One of the major accomplishments of the report is the identification of three basic complexity factors: numeric size, variety and rules," the authors say. "All complexity definitions and measures can be described by these factors."

The great variety in complexity measures found by the authors in their study and literature search reflects the fact that the contribution of each of the three factors to overall complexity depends on how information is processed by the observer, the authors say. Therefore, they say, complexity can be expressed in the formula complexity = integration of observer and basic factors (size, variety, rules).

"To achieve our ultimate goal of developing objective complexity measures for ATC tools, we need to integrate the methods presented in this report with the specifications of ATC displays," say the authors. "That is our target for the next step."

***Radar Control — Collision Avoidance Concepts: An Output of the Avoiding Action Working Group.*** U.K. Civil Aviation Authority (CAA) Safety Regulation Group (SRG). Civil Aviation Publication (CAP) 717. Second edition. Jan. 31, 2005. 20 pp. Available on the Internet at <www.caa.co.uk> or from The Stationery Office.***

The report says, "[Air traffic] controllers who have not experienced a situation where they have had to give avoiding action may not appreciate the way in which, or how quickly, a situation in which separation is lost can develop into one where there is a risk of collision."

Following a loss-of-separation incident in 1997, the Joint Airprox Assessment Panel of the U.K. Civil Aviation Authority (CAA) recommended that CAA act to ensure that emergency-training programs for controllers teach controllers to use the words "avoiding action" when immediate action by a pilot is needed to avoid the risk of collision when a loss of separation occurs. CAA accepted the recommendation and established a group composed of controllers and pilots to review the factors that make "avoiding action" instructions suitable.

"This document contains an overview of the various factors involved and provides a number of example scenarios and offers guidance on 'avoiding action' instructions that may be suitable," says the report.

## Regulatory Materials

***Airworthiness Approval of Traffic Alert and Collision Avoidance Systems (TCAS II) Version 7.0 and Associated Mode S Transponders.*** U.S. Federal Aviation Administration (FAA) Advisory Circular (AC) 20-151. Feb. 7, 2005. Figures, tables, appendixes, references, glossary. 54 pp. Available from FAA via the Internet at <www.airweb.faa.gov> or from FAA by mail.****

This AC offers guidance in obtaining airworthiness approval of TCAS II, version 7.0, certified to Technical Standard Order (TSO)-C119b, and associated Mode S transponders. It does not refer to other versions of TCAS or transponders. Guidance is not mandatory, and other methods of compliance are possible.

The AC describes TCAS II as "an airborne traffic-alert and collision avoidance system that interrogates ATC [air traffic control] transponders in nearby aircraft and uses computer processing to identify and display potential [collision threats] and predicted collision threats. The system is designed to protect a volume of airspace around the TCAS II–equipped aircraft."

A TCAS II installation may consist of a TCAS II processor; a top-mounted directional antenna; a bottom-mounted blade or directional antenna; a Mode S transponder with control panel and top and bottom antennas; a traffic advisory display with control panel; resolution advisory displays; an overhead speaker for voice messages; caution or warning lights; and associated wiring.

The AC describes components of a TCAS II system, development of a comprehensive certification plan and criteria for processes such as aircraft-performance data collection and analysis, verification and validation of software, and evaluation of aircraft maneuvers. An example of a TCAS II supplement to an airplane flight manual is included, with illustrations and instructions for flight crew about system limitations, operational procedures, maneuvers and actions recommended by the system, expected flight crew responses and other information.

Related and applicable documents are identified from U.S. Federal Aviation Regulations, ACs and TSOs; RTCA industry documents; and SAE International Aerospace Recommended Practices.

***Guidance for Approved Model List (AML) Supplemental Type Certificate (STC) Approval of Part 23 Airplane Avionics Installations.*** U.S. Federal Aviation Administration (FAA) Advisory Circular (AC) 23-22. Jan. 27, 2005. Figures, appendixes, references, glossary. 42 pp. Available from FAA via the Internet at <www.airweb.faa.gov> or from FAA by mail.****

This AC offers guidelines for using the AML STC process to obtain installation approval of avionics in airplanes certificated under Part 23 of the U.S. Federal Aviation Regulations. Guidance information addresses the following topics:

- Avionics eligible for the AML STC process;
- The model qualification process used by the STC holder and FAA to either create or edit the AML; and,
- The level of detail required for installation instructions for an AML STC certificate, including a list of acceptable equipment that can be integrated under the STC.

FAA says that this AC augments and clarifies information provided in certain FAA ACs, Orders, Notices and policy statements. Affected documents are identified, as are related FAA documents.

A generic model of the qualification process, diagrams and sample documents are included to aid FAA personnel, equipment manufacturers and avionics-equipment installers.

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***Minimum Flight Crew.*** U.S. Federal Aviation Administration (FAA) Advisory Circular (AC) 23.1523. Jan. 12, 2005. Figures, appendixes, references. 30 pp. Available from FAA via the Internet at <www.airweb.faa.gov> or from the U.S. Department of Transportation (USDOT).*****

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This AC describes an acceptable method that may be used to show compliance with certification requirements for minimum flight crew on aircraft certified under U.S. Federal Aviation Regulations Part 23, *Airworthiness standards: Normal, utility, acrobatic and commuter category airplanes.* The method described is neither mandatory nor regulatory, and it may be used to determine workload factors and related issues for Part 23 airplanes.

The AC says, "Historically, the majority of Part 23 airplanes have been certified for single-pilot operation. It is not expected that this situation will change, as most of the newly developed Part 23 airplanes are being designed from the onset to be operated as a single-pilot airplane."

The AC recommends evaluation criteria for single-pilot commuter-category operations for adequacy of cockpit layouts, display formats, information presentation, control operations and system-operation logic to support single-pilot operation. The AC says that FAA encourages participation and coordination from airplane manufacturers and modifiers, flight test pilots and engineers, design-evaluation engineers and human factors–evaluation engineers, and FAA designees.

Information in the AC and annotated reference materials (regulations, books, reports, journal articles and forms) discuss topics such as performance measures, measurement and assessment techniques, comparison of workload measures, workload and errors, and data collection. ■

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# B-737 Enters Excessive Descent Rate During Coupled ILS Approach

**The Australian Transport Safety Bureau report said that a number of factors led the flight crew to believe that the instrument landing system was usable although a notice to airmen advised that the glideslope was being tested and was not to be used for navigation.**

— FSF EDITORIAL STAFF

The following information provides an awareness of problems through which such occurrences may be prevented in the future. Accident/incident briefs are based on preliminary information from government agencies, aviation organizations, press information and other sources. This information may not be entirely accurate.

AIR CARRIER

## Crew Receives 'Sink Rate' Warning

**Boeing 737. No damage. No injuries.**

The flight crew intended to conduct a visual approach to an airport in Australia that had visual meteorological conditions (VMC). The report said that the crew were aware of a notice to airmen (NOTAM) advising that the instrument landing system (ILS) glideslope signal for Runway 23 was being tested and was not to be used for navigation.

The report said that after receiving a request to make the ILS Runway 23 localizer available for a training flight, the maintenance technicians had released the localizer for operational use while continuing pre-calibration testing of the glideslope.

"Consequently, the [localizer] (with the ILS identification code) was serviceable while the [glideslope] was operating intermittently and not available for operational use," the report said.

The first officer was flying the aircraft on autopilot. During the turn onto final approach, the crew observed that the flight instruments indicated that the ILS was operating. The approach controller then told the crew, "You should get visual shortly, but you're cleared for the 23 ILS approach."

The report said, "The controller later reported that at the time, the fact that the glide[slope] was not available had slipped his mind and he reverted to his normal radiotelephony phraseology for aircraft on final. The inadvertent slip by the approach controller was the final action of a number of lapses or omissions that led the pilots to believe that the ILS was available, despite previous advice."

The flight crew decided to continue the approach with the autopilot coupled to the ILS. About 20 seconds after the autopilot captured the glideslope signal, the aircraft began to descend rapidly, and the terrain awareness and warning system (TAWS) issued a "sink rate" warning.

The captain assumed control of the aircraft and decreased the descent rate. During this time, the TAWS issued a "pull up" warning.

"The [captain] reported that because they were visual and there were no terrain concerns, he used minimal control inputs during the recovery from the descent," the report said. "Information from the aircraft's flight data recorder indicated that the maximum rate of descent was 6,100 feet per minute and that [the aircraft] had descended to a radio altitude of 1,180 feet above ground level (2,000 feet above mean sea level) before resuming the approach profile."

## Reverse Thrust Worsens Directional Control Problem

**McDonnell Douglas MD-82. No damage. No injuries.**

The flight crew were cleared to conduct an instrument landing system (ILS) approach to Runway 13 at an airport in Indonesia at night. Visibility was four kilometers (two statute miles) with light rain, and surface winds were from 050 degrees at eight knots.

The airplane was at 2,000 feet and about 19 kilometers (10 nautical miles) from the airport when the crew observed the runway. The airplane was landed in the touchdown zone of the runway and decelerated normally. At about 60 knots to 80 knots, the airplane began to drift slowly right. The pilot flying applied left rudder and set the thrust reversers to a maximum engine pressure ratio (EPR) of 2.0.

Both pilots applied maximum wheel braking, but the airplane continued to drift toward the right side of the runway. The pilot flying told the pilot not flying to call out "brace for impact" on the public-address system. The airplane came to a stop with the right main landing gear about one meter (three feet) off the right side of the runway.

The pilot flying told the cabin attendants that an emergency evacuation was not required and to evacuate through the left front door.

The incident report said that the aircraft operating manual (AOM) prohibited use of more than reverse-idle thrust below 60 knots on a wet runway. The AOM said, "If difficulty in maintaining directional control is experienced during reverse-thrust operation, reduce thrust as required and select forward idle, if necessary, to maintain or regain directional control."

## Bleed-air Switches Omitted During Climb Check

**Boeing 737-200 Advanced. No damage. No injuries.**

Soon after the flight crew established the airplane in cruise at Flight Level (FL) 320 (approximately 32,000 feet) during a flight from Spain to Ireland, the cabin-altitude warning horn sounded. The crew donned their oxygen masks, selected the "SEAT BELTS" sign and conducted the "Cabin Altitude Warning" checklist.

The incident report said that the crew were not able to reduce the cabin altitude, which was about 11,000 feet to 12,000 feet and increasing at slightly less than 2,000 feet per minute. The captain called for the "Emergency Descent" checklist and initiated an emergency descent. The first officer said that maximum cabin altitude was about 15,000 feet.

During the descent to FL 100, the crew observed that the engine bleed-air switches were in the "OFF" position and that the auxiliary power unit (APU) was engaged. The cabin-services supervisor said that the passenger oxygen masks deployed and that several passengers were trying to don their masks before pulling them down. A cabin attendant said that some passengers showed signs of hypoxia.

"Some [passengers] appeared to be dizzy and laughing, and some did not bother to put on their oxygen masks," the report said.

The cabin crew then demonstrated the proper use of the masks. The flight crew diverted the flight and landed without further incident at an airport in France. None of the 116 occupants was injured.

The incident report said that the captain had been asked by the ground-handling agent to expedite his departure to accommodate an arriving aircraft and had started the engines 18 minutes ahead of schedule. Because the airplane was at maximum certified takeoff weight and the departure procedure required a turn soon after takeoff, the crew selected the APU "ON" and the bleed-air switches "OFF" for departure. The crew said that they conducted the "After Takeoff" checklist and the "Passing FL 100" checklist and observed no cabin-pressure abnormalities. The report said that the APU can supply bleed air for one air-conditioning pack up to 17,000 feet.

"It is clear that the 'After Takeoff' checklist was not fully accomplished, as the engine-bleed switches remained in the 'OFF' position for the entire climb," the report said. "The APU did supply bleed air to the bleed-air duct and achieved aircraft pressurization up to the very initial stage of the cruising level."

AIR TAXI/COMMUTER

## Broken Bracket Found After Gear Failure

**Britten-Norman BN-2A Islander. Substantial damage. No injuries.**

Daytime visual meteorological conditions prevailed for a scheduled air-taxi flight in the United States. The pilot, who had two passengers aboard, said that he felt a significant airframe vibration and heard a rumbling noise as the airplane slowed during the landing roll.

When the pilot applied the wheel brakes, the airplane veered left. The pilot said that he was unable to keep the airplane on the runway. It rolled off the runway and struck a drainage ditch.

The report said that maintenance personnel found a broken landing gear oleo attachment bracket on the left main landing gear strut assembly.

## Engine-out Drill Leads to Control Loss

**British Aerospace Jetstream 32. Substantial damage. One minor injury.**

The pilots were conducting a scheduled flight in Sweden in daytime visual meteorological conditions and with no passengers or flight attendant aboard the airplane. Before takeoff, they had discussed simulating an engine failure to help prepare the 29-year-old copilot, who had 660 flight hours, including 237 flight hours in type, for an upcoming proficiency check.

The report said that the 64-year-old commander, who had 31,000 flight hours, including 2,000 flight hours in type, had experience as a flight instructor but was not qualified or authorized by the company to serve as a flight instructor in the Jetstream.

During initial climb, the commander moved the right throttle lever to idle to reduce thrust. The copilot had no difficulty controlling the airplane, and the pilots decided to simulate an engine failure during approach.

The airplane was at about 3,500 feet when the commander again moved the right throttle lever to idle. The pilots conducted a visual approach and extended the landing gear and 20 degrees of flap. Soon after the aircraft crossed the runway threshold at about 16 feet above ground level, the airplane yawed and rapidly rolled right. The report said that indicated airspeed had decreased to 96 knots when the roll began; minimum single-engine control speed ($V_{MC}$) was 98 knots. Both pilots applied full aileron control and full rudder control but were unable to stop the roll.

Indicated airspeed was about 80 knots — about four knots below stall speed — when the right wing tip struck the ground. The landing gear fractured, and the airplane slid on its belly for about 50 meters (164 feet) before coming to a stop. The report said that the copilot received an injury to his leg.

CORPORATE/BUSINESS

## Left Main Gear Collapses During Landing

**Cessna 421. Substantial damage. No injuries.**

The pilot was en route in daytime visual meteorological conditions to pick up passengers at an airstrip in Tanzania. After arriving at the destination, the pilot flew around the airstrip to check the runway for obstructions and the wind sock for wind direction.

The wind was from the southeast, and the pilot decided to land the airplane on Runway 16. The report said that the runway surface was compacted volcanic soil and was in very good condition.

The pilot extended the landing gear on final approach and observed indications that the gear was down and locked. Soon after touchdown, the left wing began to drop, and the pilot heard an aural warning. The airplane began to veer left, and the pilot applied right rudder to keep the airplane on the runway centerline. The airplane then abruptly turned about 140 degrees left and came to a stop on its lower fuselage.

Examination of the airplane to determine why the left main landing gear collapsed soon after touchdown was pending when the preliminary report was issued.

## Crew Encounters Fog During Landing Flare

**Raytheon Beech King Air 300. Substantial damage. No injuries.**

The automatic terminal information service was reporting two statute miles (three kilometers) visibility and scattered clouds at 100 feet when the flight crew were cleared to conduct an instrument landing system (ILS) approach to a 3,998-foot (1,219-meter) runway at a U.S. airport.

After flying the airplane over the final approach fix, the pilot was told by the tower controller that visibility was 0.75 statute mile (1.21 kilometers) and that the airport had an indefinite ceiling at 100 feet.

The pilot and copilot told investigators that the airplane was about 200 feet above ground level when the runway lights and the runway threshold became visible. The pilot said that when he flared the airplane for landing, "fog rolled over the runway, severely limiting my view of it." He said that he had to "feel for the runway," which extended the touchdown.

The crew applied maximum wheel braking and reverse thrust. The airplane overran the runway and struck a localizer antenna 557 feet (170 meters) beyond the departure end of the runway. None of the six occupants was injured.

The report said that the probable causes of the accident were "the pilot's failure to perform a missed approach after losing sight of the runway and the misjudgment of distance on the runway, which led to an overrun."

## Rejected Takeoff Results in Overrun

**Rockwell Sabreliner 80. Substantial damage. No injuries.**

Daytime visual meteorological conditions prevailed when the flight crew began to conduct a takeoff from a 5,599-foot (1,708-meter) runway at an airport in the United States. The captain said that just after the first officer called out $V_1$, the five occupants of the airplane heard a loud bang, and the airplane swerved left.

The captain applied maximum wheel braking and deployed the thrust reversers to reject the takeoff. The airplane overran the runway, struck a fence and trees, crossed a road and came to a stop in a newly plowed field about 1,300 feet (397 meters) from the departure end of the runway.

The U.S. Federal Aviation Administration defines $V_1$ as "the maximum speed in the takeoff at which the pilot must take the first action (e.g., apply brakes, reduce thrust, deploy speed brakes) to stop the airplane within the accelerate-stop distance [and] the minimum speed in the takeoff, following a failure of the critical engine at $V_{EF}$ [the speed at which the critical engine is assumed to fail during takeoff], at which the pilot can continue the takeoff and achieve the required height above the takeoff surface within the takeoff distance."

## Wing Tanks Found Empty After Forced Landing

**Cessna 337C Skymaster. Substantial damage. One fatality, one serious injury.**

The airplane was 1,000 feet above ground level during a visual approach to an airport in Italy in daytime visual meteorological conditions when the pilot reported a loss of power from both engines.

The pilot received serious injuries and the passenger was killed during the forced landing in a corn field. The report said that the main fuel tanks were found empty and the auxiliary fuel tanks were found full of fuel.

## Engine Fails in Landing Pattern

**Aero Vodochody L-39ZO Albatros. Damage not specified. No injuries.**

Daytime visual meteorological conditions prevailed when the pilot flew the former military jet trainer into the landing pattern at an airport in England. The private pilot had 1,574 flight hours, including 50 flight hours in type.

The report said that the pilot intended to conduct a "run and break" pattern entry, flying the airplane parallel to the runway before turning crosswind to enter the downwind leg. There were 450 kilograms (992 pounds) of fuel aboard the airplane; the recommended minimum fuel quantity on the downwind leg is 300 kilograms (662 pounds).

Indicated airspeed was 220 knots when the airplane entered the pattern. The pilot moved the throttle lever to idle and extended the speed brakes when he began the turn onto the crosswind leg. After airspeed decreased to 180 knots, he extended the landing gear and moved the throttle lever to a position corresponding to a normal thrust setting and airspeed for approach. He decided to leave the speed brakes extended until airspeed decreased to 165 knots, the maximum airspeed for flap extension.

The pilot then heard a change in the engine sound and observed that the airplane was descending through 850 feet above ground level (AGL); the pattern altitude is 1,000 feet AGL. He moved the throttle lever full forward, but the engine did not respond. He declared mayday, a distress condition, and reported that the engine had failed.

The pilot decided that not enough time was available to attempt a restart and that altitude was insufficient to eject, and flew the airplane toward a recently harvested wheat field. The airplane touched down firmly on the harvested field, struck a hedge and came to rest in a field of standing wheat.

"The nose gear collapsed, but the aircraft remained structurally intact," the report said.

The cause of the engine failure was not determined. The report said that a contributing factor might have been a seizure of the inlet directing body (IDB) mechanism, which maintains stable airflow between the low-pressure compressor and the high-pressure compressor. The report said that the seizure might have been prevented by compliance with a service bulletin, issued by the engine manufacturer (Ivchenko) in Russian and Spanish in 1980, and recommending periodic torque checks of the IDB mechanism.

## Power Loss Leads to Landing in Swamp

**Piper PA-12 Super Cruiser. Damage not specified. One minor injury.**

The airplane was being flown about 150 feet above ground level and had been airborne about 2.5 hours on a pipeline-inspection flight in Canada when the engine began to run roughly. The pilot, who had been using fuel from the right auxiliary tank (the left auxiliary tank was empty), selected the left main fuel tank. A power loss then occurred.

The pilot selected the right main fuel tank but was unable to restart the engine. The report said that he conducted a forced landing in a slough (swamp). The airplane overturned and partly submerged.

"The pilot was able to free himself as water entered the cockpit," the report said. "Reportedly, the main tanks held sufficient fuel for several hours of flight."

## Helicopter Strikes Terrain in Snowstorm

**Bell 206B. Destroyed. One serious injury, one minor injury.**

The helicopter was being flown under a visual flight rules (VFR) flight plan on a multi-leg ferry flight in Canada. About one hour after departure, the helicopter encountered snow showers and reduced visibility, and the chief pilot took the controls.

"The visibility continued to worsen until the pilots encountered whiteout conditions, and they lost all visual reference with the terrain," the accident report said. "Shortly thereafter, the helicopter struck the snow-covered surface of a field."

The report said that the accident's causes and contributing factors were that "the chief pilot's decision to continue a visual flight into instrument meteorological conditions resulted in his inability to maintain control of the helicopter … ; the chief pilot's decision to continue into deteriorating weather conditions was influenced by a mistaken expectation that the weather … was better than the reported conditions and the pressure to reach [the destination] on the day of the occurrence; [and] the pilots disregarded the safe limits with regard to VFR flight."

The report also said that the pilots' use of a global positioning system receiver "assisted them in navigating into weather conditions in which they could not safely fly the helicopter."

## Bird Strikes Helicopter Involved in Search Flight

**Sikorsky S-61N. Minor damage. No injuries.**

Daytime visual meteorological conditions prevailed for the search of the North Atlantic Ocean off the coast of Ireland for "a missing trawler-man," the accident report said. Several trawlers also were being used in the search operation, and the trawlers attracted many sea birds.

After searching, as the crew flew the helicopter to a landing site in Ireland, they observed a large black and white bird.

The report said, "The pilot took evasive rolling action to his right. However, the bird impacted on the clear Perspex panel and broke it, just above the copilot position."

The captain said that because he had rolled the helicopter to the right, the impact probably was less serious than it otherwise might have been.

## Tie-down Strap Not Removed Before Takeoff

**Bell 206L-4 LongRanger IV. Destroyed. One fatality.**

A loss of control occurred when the pilot began to fly the helicopter from an offshore oil-pumping platform in the Gulf of Mexico to make room for another helicopter that was being landed for refueling in daytime visual meteorological conditions.

The other pilot said that the accident helicopter pitched nose-up, pivoted right and began to drift left across the 40-foot by 60-foot (12-meter by 18-meter) helideck. The helicopter then struck a safety fence, fell 161 feet (49 meters) to the water and sank.

The other pilot circled the platform for about 30 minutes to search for survivors but observed only small pieces of debris from the accident helicopter, the tail boom, a partially inflated helicopter float and one life vest. The wreckage and the pilot's body later were recovered from the water.

The accident helicopter's rear tie-down strap and right front tie-down strap were found in a storage compartment on the helideck. The left front tie-down strap was found attached to its tie-down fitting on the helideck and extended randomly on the helideck and the damaged safety fence. ■

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