The Role of Feedback In the Airline Industry

Icarus, the mythological aviator, fell to his death as a consequence of poor judgment, inadequate structural design and ignorance of the flight environment — weaknesses that continue to challenge modern-day aviators. However, sophisticated flight data recording systems now make it possible to gather vital information that can be analyzed and used to manage risk and enhance safety. To this end, the Flight Safety Foundation is leading an industry-wide effort in the United States on the benefits of flight data analysis, which has been accepted and proven by many non-U.S. airlines.

by
John H. Enders, Vice Chairman
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Risk management has been the focus of expert attention for many years in a variety of industries. Many approaches for controlling risk have been developed and practiced successfully, especially in insurance risk assessment.

Nevertheless, understanding of risk assessment is not widespread, and there are many people who are not sure how to manage risks in their businesses.

For many of these people, such ignorance is not threatening to life or property, however critical it may be to the economic survival of their enterprises. On the other hand, in certain activities, where failures involve catastrophic effects on humans, this ignorance cannot be tolerated. Indeed, in recent years managements of such enterprises as chemical, nuclear and air transport industries have become more risk-prevention conscious.

Successful management of risk entails thorough knowledge of hazards at all levels and communication of this knowledge to all engaged in the enterprise. Top management must be committed to an effective risk management process and management's commitment must be visible and perceived as genuine. The term "situational awareness" has been used to describe this condition. An essential aspect of corporate situational awareness is a timely and accurate information feedback process.

Aviation, unlike many other endeavors, involves the direct daily participation of the traveling public, who entrust their well-being to strangers during flights. For this reason, airlines, manufacturers and regulators have been held accountable for air safety by the courts and by the public. The Duty of Care is imposed on everyone in our business. It is not a choice. And we must work continuously to ensure the lowest possible risk to those for whose safety we are responsible.

Icarus Demonstrated Risk Management Failure

Aviators remind us that aviation safety problems have been with us since the mythological flight of Icarus, who flew too close to the sun. Heat melted the wax that held the feathers on his rudimentary wings, and he fell to his death as a consequence of poor judgment, inadequate structural design and ignorance of the flight environment.

Leonardo da Vinci's intriguing designs for flying machines are magnificent and show some primitive concern for the operator's safety. In the early history of aviation, balloon flights, glider flights and powered heavier-than-air flying machine flights were long on ingenuity but short on risk control. It was not until the beginning of this century that aviation began to be taken seriously. Until then, feedback about failures and successes usually came through personal correspondence of aviation enthusiasts and journals of professional societies. The Wright brothers incorporated some elements of safety in their designs, and progress in airplane development relied heavily on feedback from their flight experiments.

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As flying captured the world's attention and pilots began to train other pilots, the need for consistent and substantive pilot training became obvious. Rudimentary standards of pilot qualifications emerged. The National Aeronautics Association was the pilot licensing authority in the United States until the Civil Aeronautics Agency was established in the late 1930s. Similar efforts took place in Europe, Russia, Japan, China, South Africa, India and Australasia about the same time.

World War I was the first "refining event" for aviation, taking it away from the exclusivity of enthusiasts and employing the airplane as a tactical and strategic combat tool. As more people became involved with the utility of aviation, the effort began to reduce losses of aircraft and their crews. Performance targets were established by customers that led to greater structural and powerplant reliability and efficiency. Other safety devices appeared, such as parachutes. The first formal information feedback loops were thus established between designers, builders and users.

One of the early reports of the U.S. National Advisory Committee for Aeronautics (NACA) [the U.S. Aeronautics and Space Administration's (NASA) predecessor], when it was established in 1915, was a translation of a 1914 French treatise, *On the Problem of Fire in Airplanes*, arising from early aerial combat experience. This drew engineering attention to designs that would reduce the risks of fuel leaks. The early attention to risk control in aviation, though it was not identified as such at the time, responded to the terrible costs in lives and matériel from military aviation accidents.

Following World War I, as civil transport aviation developed, the lack of adequate flight planning and airport condition information, combined with general ignorance of flight environmental hazards (e.g., winds, turbulence, ice, storms, etc.) and lack of uniform standards, resulted in a high incidence of fatal aircraft accidents. It took the deaths in aircraft accidents of Knute Rockne, then a well-known football coach at the University of Notre Dame, and other celebrities and politicians to galvanize the U.S. Congress into enacting the Civil Aeronautics Act of 1938, which established a formal set of procedures and standards for civil flight and for their enforcement. This was the beginning of serious procedural risk management for U.S. civil aviation.

U.S. and U.K. Regulations Set World Standards for Safe Flight

The resulting regulatory structure established minimum acceptable standards for the design and operation of aircraft. Later, the criteria for licensing of aviation personnel and other support activities for civil aviation were codified. The British carried out similar regulatory activities during the same period, and, for nearly 60 years, either the U.S. Federal Aviation Regulations (FAR) or the British Civil Air Regulations (CAR) were adopted, with only slight differences, by virtually every country in the world. The former Soviet Union was a notable exception, having independently developed its aviation standards. Despite differences in detail, the overall intent of its standards was not substantially different from those developed in the West.

As modern aircraft designs became more sophisticated, regulations were upgraded, creating some significant differences between national regulations. During the past decade, therefore, vigorous efforts have been made to combine the different codes into a new, international body of standards and regulations — Joint Airworthiness Regulations (JAR). With the breakup of the former Soviet Union, its own regulatory standards, many of which are more stringent than those in the West, are being integrated into the new body.

From the design and manufacturing perspective, NACA and later NASA, as well as the U.S. Federal Aviation (FAA) and their worldwide counterparts, supported the aeronautical industry through research and development programs that sought ever-increasing efficiencies and performance. A government/industry subcommittee on aircraft operating problems had a major influence on NASA's applied research in aircraft fire prevention, human factors, severe weather detection, lightning protection, landing and takeoff precision navigational guidance, aircraft handling qualities and control systems, poor weather operation, icing detection and removal, and runway and tire traction. Such technical information is relayed to the design, manufacturing and operating communities for the further refinement of safe aircraft operations.

Since the emergence of civil transport aviation following World War II, the reduction of accidents and accident rates has been impressive. Presently, the world's scheduled airlines carry in excess of one billion passengers each year, with 12 to 18 fatal accidents a year and an annual loss of life of about 600 persons. The United States experiences about 3 to 5 fatal accidents annually with 100 to 120 fatalities per year in scheduled air transport operations. This level of safety was hard-won during five decades and involved the exchange of information between all members of the aviation community.

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From a statistical point of view, the risk of losing one's life on a scheduled airline flight anywhere in the world is slightly better than one in one million. For travelers on U.S. airlines, the risk is better than one in two million. To put it another way, if a person were born on a U.S. scheduled aircraft and never left the airplane, he or she would be 125 years old before being involved in a fatal accident. And even then, he or she would have slightly more than a 50 percent chance of survival.

These may seem to be comforting statistics. But the disturbing aspect of them is that the *rate* of improvement has flattened during the past several years. From a risk management standpoint, a retrospective review of each of the 12 to 18 fatal accidents annually in recent years indicates that they should have been preventable, given the collective knowledge that exists. We have not been able to successfully marshal all our resources to access and use this bank of knowledge, which is available from disparate governments, industries, research laboratories and other entities.

We cannot understand yet, with certainty, why well-trained, highly experienced pilots deviate from what they know and were taught and make flawed judgments that lead to accidents. We do not fully understand the human-machine interface and how cultural differences may lead to varying interpretations of the logic in display and control systems.

Feedback of Safety Information Remains Essential to Further Improvements

Feedback of safety information in the airline industry takes many forms. The corporate executive must set the tone for effective risk management and attention to safety. High morale and employee enthusiasm are critical to the success of effective risk management. Employee motivation to perform at a high level of quality is also essential. Motivation can be accomplished in many ways, with cultural variations. In Japan, for instance, a major airline ends its maintenance-team meetings each morning with a strong encouragement for each individual on the team to "look for flaws" in equipment, procedures, work habits, etc., so that the inspection and repair process can be as reliable as possible.

Individual airlines have their own internal schemes of communicating critical safety information, generally through a dedicated safety manager.

This person has full access to the entire company's operations and ideally reports directly to the chief executive. The safety manager must develop trust and credibility with both line workers and management. This position, which is much like an ombudsman, is critical to effective risk management within the organization.

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The full-motion, visual-display flight simulator is illustrative of highly effective feedback. Its introduction has been a major step forward in safety training, where dangerous flight situations can be realistically simulated for both research and crew training. The simulator trainer can concentrate on demonstrated crew deficiencies to bring the individual(s) to acceptable levels of performance. This is a very powerful feedback tool that has dramatically increased the effectiveness of training. Its value for research has been demonstrated in many areas, including cockpit display development, braking system performance improvement, and development of wind shear recovery procedures.

Recurrent training of cockpit crews, cabin crews, maintenance staff and ramp service personnel provides regular and frequent safety feedback. Most airlines publish a regular internal safety document to maintain high individual awareness of safety and risk management.

Through international and national air transportation associations, a great amount of industry information is circulated and discussed among airlines. The sharing of safety problems and solutions is vigorous through private and public organizations such as the Air Transport Associations of the United States, Canada and Europe; the Australasian Airlines Flight Safety Council; the International Civil Aviation Organization; the International Air Transport Association and others.

The authorities of the more developed countries monitor safety through a variety of means. In the United States, airlines are required to file reports of system discrepancies (SDR) with the FAA. SDRs are maintenance-oriented and are shared with all U.S. operators. U.S. National Transportation Safety Board (NTSB) accident investigation findings and recommendations are filed with the FAA and other authorities as well as conveyed to the airline and manufacturing industry. In safety-critical situations, the FAA issues airworthiness directives that mandate actions by the airlines or manufacturers to eliminate hazards. The FAA may also issue advisory circulars that provide specialized information to assist operators or manufacturers in complying with regulations or avoiding hazards. FAA inspection activities at the design, manufacturing and operations levels of aviation provide feedback on current practices. Inspection of air traffic control and air navigation facilities ensures a feedback that maintains a high standard of performance. Other nations employ similar methods and actions to manage risk to an acceptable level.

Other nonofficial external influences provide effective feedback in an informal way. Probably no other industry enjoys the high level of popular attention to its activities that aviation does. In the United States, Europe and Australasian countries, there is a strong aviation trade press that communicates safety information. Many commercial publications not only carry economic and business news about the aviation industry; they also feature safety information that heightens the readers' awareness of safety and the need for risk management. The daily print and broadcast media also play a role, albeit often a sensational one. Though hardly technically rigorous, this coverage has the effect of keeping industry and government decision-makers focused on safety. Unfortunately, the effect is sometimes skewed toward the wrong problem.

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The courts also provide effective feedback to the industry, and the fear of legal action has focused the attention of more than one executive on the task of controlling risk.

Foundation Built on Feedback

The Flight Safety Foundation is also in the information feedback business. Foundation doctrine is to anticipate and study flight safety problems and to collect and disseminate safety information for the benefit of all who fly. The most safety-conscious airline shares the same airspace with the less informed or even careless operator, so it is of benefit to invest in the education and awareness-raising of such operators. The Foundation, with more than 561 member organizations in 73 countries, provides an information collection and feedback function that many lesser-developed aviation industries rely on for aviation safety information.

As an apolitical, independent, nonprofit and international organization, we benefit from our nonofficial status because we avoid a great many of the postured responses that many businesses are obliged to present to their peers, governments and media. Because we have no enforcement authority, ours is a task of friendly persuasion. We are, as several aviation leaders have described the Foundation, the "safety conscience" for the industry. We have support from major manufacturers and airlines (which have a sense of responsibility as well as an enlightened self-interest) to make the skies as safe as possible.

The agendas of the Foundation's annual safety seminars, held in locations throughout the world for the past 45 years, feature a strong program of accident prevention methodology presented by the best safety experts in industry, government and academia. Their aim, of course, is to provide effective feedback to the aviation community about hazard identification, design, training, inspection, procedures, trend analysis, etc., to use collective knowledge for the prevention of accidents.

Feedback occurs in other forums such as industry association meetings, industry-government committees dealing with specific safety topics, meetings with other independent associations focusing on specific areas of safety improvement and computer-based data exchanges.

Another means of obtaining information for feedback to the airline industry is the Foundation's confidential safety audits of corporate and airline operations. This is a valuable method of gaining firsthand information about how companies comply with their own operating standards, how they value safety and how they manage risk. We share this information on a non-attributable basis with our members through the regular publications we produce as well as our safety seminars. In addition, we complete the feedback loop by special workshops and conferences that focus on specific safety problems in various regions of the world.

During the past three years, the Foundation helped the former Soviet Union to establish a Flight Safety Foundation in what is now the

Commonwealth of Independent States (CIS). We are actively working through FSF-CIS to inculcate a safety-conscious culture in Aeroflot and the more than 60 emerging airlines in the Commonwealth. Coordination of risk management information is a real challenge. For their part, the agencies of the former Soviet Union have been quite generous in sharing safety and accident information they have developed for their aviation operations. We have, in turn, shared this data with our worldwide membership.

Trend Analysis Proves Itself A Powerful Risk Management Tool

Air carrier operations have a unique feature during flight: the operation is unsupervised, except by the aircraft commander and the flight crew. While the level of professionalism is high by ordinary standards, airline managements and maintenance departments have been dependent for many years on qualitative reports of system deficiencies and other assessments from the crew. The very nature of human behavior ensures a significant lack of precision in this method.

A common complaint among safety analysts during the past half-century has been that while we have information on accidents, the lack of reliable information about "almost accidents" (incidents) has hampered additional direct action to prevent accidents.

To elicit more information about safety incidents, the FAA and NASA embarked on a program in the 1970s to develop a confidential scheme of safety feedback reporting wherein anyone in the U.S. aviation system could report safety deficiencies to NASA as a disinterested third party without fear of FAA punitive action in those cases where the deficiency involved the reporter. NASA's Aviation Safety Reporting System (ASRS), funded by the FAA, has been an unqualified success, with more than 10,000 monthly reports describing procedural, training, air traffic control, mechanical and other human factors-related errors. Trend analysis, special reports and direct relay of overtly hazardous situations to the FAA for corrective action have greatly benefited the aviation system. As an indication of the value of this program, it has been emulated in the United Kingdom, Australia, Germany, Canada, Japan, the former Soviet Union and other countries. A common feature of each of these programs that is essential to their effectiveness is the regular publication and distribution of information to the aviation community. These publications (*CALLBACK, CHIRP,* etc.) emphasize the feedback information loop. As valuable as these programs are, however, they remain anecdotal and far from a comprehensive sweep of the entire aviation operations spectrum.

For many years, air transport aircraft have carried devices that record certain flight parameters, primarily for postcrash accident-analysis purposes. Beginning with the early metal-foil devices that recorded basic information such as airspeed, altitude, etc., they have evolved into sophisticated computer systems that record more than 100 parameters of an aircraft's systems during flight.

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With the advent of modern microcomputers and the miniaturization of sensors and transmission circuits, it is now possible to record *in situ* quantitative values for a multitude of flight parameters. For the past two decades, this capability has been used to provide condition monitoring of aircraft structure and engine systems for the benefit of the engineering and maintenance departments. Now, the maintenance technician is able to track the performance of an engine component or to detect overstress of structural components. In some cases, airlines have used satellite communications to transmit onboard systems monitoring output to ground stations so that if unscheduled maintenance was needed at the destination airport, the parts and procedures could be readied for the arrival of the aircraft, thus saving downtime and keeping reliability of the operation at a high level.

The value of this kind of feedback is obvious. Greater efficiency and prompt attention to problems is a powerful risk management tool. Trend analysis of aircraft systems performance allows more confident prediction of inspection intervals and overhaul events.

During the past 15 years, some non-U.S. airlines experimented with the extension of these maintenance feedback capabilities to record operational parameter exceedances. Pioneered 25 years ago by the British Civil Aviation Authority (CAA) and British Airways, the CAA Data Recording Program (CAADRP) was gradually expanded to a comprehensive monitoring of flight performance. Accompanying this detailed look at individual flight records was a policy of preventing the use of such records for punitive action against air crews. This is necessary to gain the full cooperation of the human operators in the system.

Today, the BASIS (British Airways Systems Information Service) program is an excellent model of risk management feedback. It was designed and developed by safety professionals to provide support in capturing, investigating and analyzing safety data from incidents and accidents. Its human factors aspects facilitate investigative research into human errors throughout the system. It is a decision support tool for all levels of management in managing risk. It incorporates automatic alerting of problems and assists in setting priorities for preventive action.

More than 25 non-U.S. airlines operate some sort of program for flight data monitoring that provides trend monitoring and risk management benefits.

BASIS promotes uninhibited reporting and open exchange of all safety information inside and outside the company. BASIS provides technical and operations managers with instant access to shared safety data within the company, so that maintenance or ramp services can access safety information supplied by the flight operations department and vice versa. This has bonded the usually disparate divisions into a cohesive unit that is dedicated to reducing risk in every element of the operation. There are many benefits of this program because it is:

- Compatible with a personal computer;
- Easy to use by noncomputer literate people;
- Efficient (data can be entered promptly);
- An aid to fast investigation and report processing;
- A tool to optimize safety department resources;
- Accessible company-wide though password control;
- Compatible for an industry-wide data exchange; and,
- An important key in harnessing corporate operational expertise, while encouraging crew and individual feedback without fear of punitive action.

Other international airlines have adopted similar programs for flight data analysis programs. More than 25 non-U.S. airlines operate some sort of program for flight data analysis that provides trend analysis and risk management benefits (Table 1, page 8). U.S. airlines have not adopted such programs, mainly because of litigation concerns and individual privacy issues.

Scandinavian Airline Systems (SAS) has a Total Quality Program that includes an effective program of operational trend analysis. It provides feedback of critical performance information to all operating elements within the company.

TAP Air Portugal reads every flight record and has done so for the past 15 years. Newly upgraded captains are required to read their own flight records with the flight safety officer for one month after their promotions. Many of these people continue to read their own flight records after the required period to continue analyzing and improving their skills.

Foundation Leads Effort to Implement U.S. Flight Data Analysis

The Foundation, recognizing the importance of such programs, in 1988 held an international workshop in Taipei, Taiwan (with the sponsorship of China Airlines), to examine the successes and problems of existing digital flight data recorder (DFDR) analysis programs. Two years later, the Foundation hosted an international meeting in Washington, D.C. It invited the FAA, U.S. airlines, pilot unions and aircraft manufacturers to hear from some non-U.S. airlines that had benefited from such feedback programs.

Table 1
Non-U.S. Airlines with Flight Analysis Programs

Aer Lingus
Aeroflot
Air Canada
Air Europa
Air France
Alitalia Airlines
All Nippon Airways
Britannia Airways
British Airways
Cathay Pacific
Gulf Air
Iberia Airlines of Spain
Japan Air Lines
KLM Royal Dutch Airlines
LOT
Lufthansa German Airlines
Martinair Holland
Qantas Airways
Sabena
Scandinavian Airlines System
Singapore Airlines
South African Airways
Swissair
TAP Air Portugal
UTA

Source: Flight Safety Foundation Flight Operations Quality Assurance Program (FOQA)

Table 2
FOQA Study Purpose

- Enhance operational safety.
- Study all issues associated with introduction of FOQA into U.S. air transport operations.
- Define an advanced FOQA system.
- Provide for current digital flight data recorder capabilities.

Source: Flight Safety Foundation Flight Operations Quality Assurance Program (FOQA)

As a result of the Foundation's efforts, a one-year contract study (Tables 2, 3 and 4) for the FAA and U.S. airlines is scheduled for completion in early 1993 on the benefits of Flight Operations Quality Assurance (FOQA) programs that

Table 3
FOQA Study Scope

- $490,000, 16-month study contract.
- Applies to Part 121 and 129 operators.
- Current/planned flight data systems.
- Data usage requirements:
  - Accident investigation.
  - Pilot and crew inflight performance.
  - Training and safety programs.
  - Pilot self-management and performance improvement.
  - Air transport operations efficiency.
  - Air traffic control enhancement; and,
  - Aircraft and airport design.

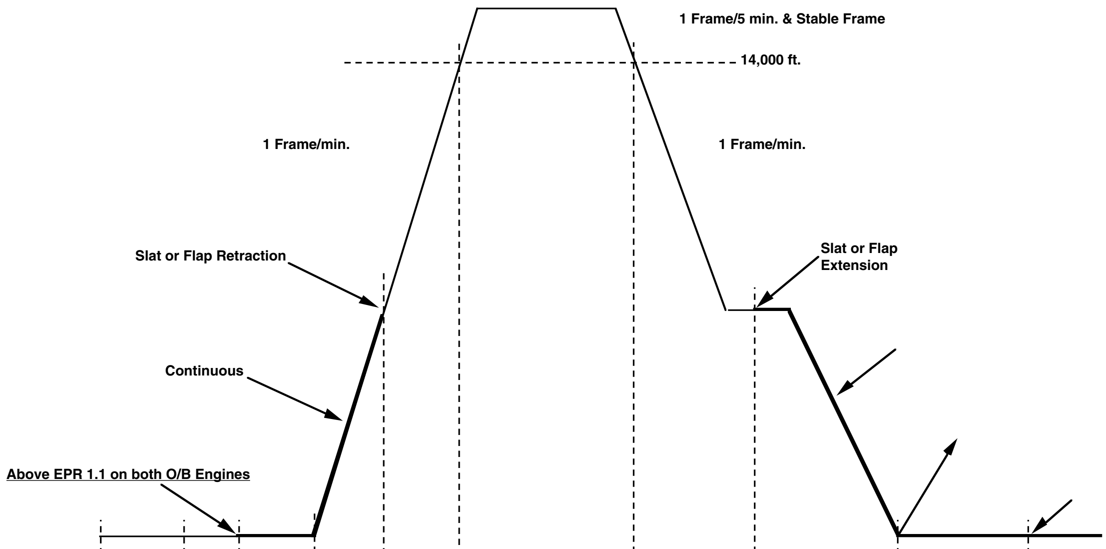
Source: Flight Safety Foundation Flight Operations Quality Assurance Program (FOQA)

Table 4
FOQA Study Tasks

- Prepare study management plan — 60 days:
  - Coordinate with industry working group.
  - Submit to U.S. Federal Aviation Administration for comment.
  - Finalize plan and obtain FAA approval.
- Conduct the study:
  - Determine current practices.
  - Define the advanced FOQA system.
  - Resolve pilot, operator and government legal issues.
- Prepare final study report.
- Prepare draft advisory circular for operator guidance.

Source: Flight Safety Foundation Flight Operations Quality Assurance Program (FOQA)

Table 5
Typical Recording Cycle for In-flight Analysis Systems



FLIGHT MODE	PRE-FLT. PF	ENG. START ES	TAXI TA	TAKEOFF TO	INITIAL CLIMB IC	CLIMB CL	ENROUTE ER	DESCENT DS	APPROACH AP		
AIDS RECORDING	I	I	I	C	C	I	I	I	C		
DFDR RECORDING			← C	C	C	C	C	C	C	C	C →

C: Continuous Recording
I: Intermittent Recording

Source: Flight Safety Foundation Flight Operations Quality Assurance Program (FOQA)

Table 6
Most Common Event Classifications

TAKEOFF

- T/O accel.
- Vertical accel.
- Rotation rate
- Pitch attitude
- Unstick speed

CLIMB

- Climb speed
- Alt. loss
- Bank angle
- Pitch attitude
- Lift margin
- Time to 1,000 ft.
- Gear up speed
- Flap/slat config.

CRUISE

- V_{mo} exceed.
- M_{mo} exceed.
- Max alt. exceed.

DESCENT/APPROACH

- Gear extend speed
- Flap/slat speed
- Approach alt.
- Glideslope deviation
- Approach speeds
- Rate of descent

LANDING

- Pitch attitude
- Flap setting
- Vertical accel.
- Heading deviation
- Go around

MULTIPLE FLIGHT MODES

- Abnormal flap/slat/speedbrake configuration
- Vertical acceleration
- Bank angle
- Flap placard
- Stick shaker
- Ground proximity warning system actuation
- Birdstrike speed

Source: Flight Safety Foundation Flight Operations Quality Assurance Program (FOQA)

Table 7
FOQA Industry Team Composition

Air Line Pilots Association-U.S.
Air Transport Association
Allied Pilots Association
American Airlines
Arinc
The Boeing Co.
Delta Airlines
McDonnell Douglas
Northwest Airlines
United Airlines
U.S. Federal Aviation Administration
U.S. National Aeronautics and Space Administration's Aviation Safety Reporting System
U.S. National Transportation Safety Board

Source: Flight Safety Foundation Flight Operations Quality Assurance Program (FOQA)

use on-board flight data recorder (FDR) capabilities to provide feedback for risk-management purposes (Tables 5 and 6, page 9). The study also calls for the Foundation to prepare a draft advisory circular for the FAA that will describe methods of satisfactorily implementing FDR programs in air transport operations. [The FAA Aviation Rule-making Advisory Committee (ARAC) also will comment on the advisory circular.]

As is the case with so many other safety issues, tort laws and the contingency fee system in the United States are factors that inhibit prompt and full exchange of vital safety information that could improve the management of risk in the aviation industry. In the past, U.S. pilots, unions had doubts about the value of quantitative recording of flight performance data. However, the major unions are now participating with industry and government representatives in the Foundation's FOQA efforts to introduce this proven feedback system to U.S. airline operations (Table 7).

Risk management in airline operations relies heavily on feedback that, though evolving in a piecemeal fashion, has nevertheless been developed to a high level. The major problems confronting further accident reduction center on the difficult and expensive task of effectively combining the huge and diverse body of safety information that will feed into qualification and training programs, systems monitoring and corrective action early enough to interrupt the accident-event chain.

In the United States, the current poor financial health of airlines and the national economy will make this challenge difficult to meet. Thus, it is more important than ever that the sharing of safety information, not only within a particular discipline but also between disciplines, becomes an essential element of feedback. In this way, subtleties of risk control can be exploited for the public good. ♦

About the Author

John H. Enders is vice chairman of the Flight Safety Foundation Board of Governors, and he is charged with technical oversight of the Foundation's activities.

Enders is a graduate mechanical engineer with a degree from Case Institute of Technology, Cleveland, Ohio, U.S. Enders conducted rocket engine research as a staff member of the U.S. National Advisory Committee for Aeronautics (NACA), the predecessor of the National Aeronautics and Space Administration (NASA). He later served as a pilot and development engineer in the U.S. Air Force before returning to NASA as a research test pilot, becoming manager of aircraft safety and operating problems research. He served as liaison member on the National Aeronautics and Space Council and as a technical advisor to the associate administrator for aviation safety at the U.S. Federal Aviation Administration.

Enders represents the Flight Safety Foundation at numerous aviation safety seminars and on various committees throughout the world and frequently presents papers on aviation safety. This article is adapted from a recent presentation about feedback made to the American Nuclear Society.

Prior to his appointment as vice chairman in May 1991, Enders had served the Foundation as its president for more than a decade.

Aviation Statistics

U.S. General Aviation: Instructional Flying and Safety

by
Shung Huang
Statistical Consultant

Instructional flying, defined by the U.S. Federal Aviation Administration (FAA), refers to a major segment of general aviation activity. It includes any use of an aircraft for the purpose of formal instruction with a flight instructor aboard or flight maneuvers specified by the flight instructor.

Growth and Recession

In 1930, instructional flying recorded a total of 300,000 aircraft hours, accounting for 28 percent of the general aviation total annual flying time. Under the impetus of wartime requirements, the U.S. Congress adopted the Civilian Pilot Training Act in 1939 to stimulate flight training. Instructional flying time in 1942 rose to a total of 2.8 million flight hours, accounting for 71 percent of all flying time, an increase of 900 percent over that of 1930. The adoption of the GI Flight Training Program (for U.S. military veterans) expanded general aviation instructional flight even more. In 1946, annual instructional hours rose to 5,996,000 and to 10,353,000 hours in 1947, the height of instructional flight time.

Public interest in flying began ebbing in 1948, and total instructional hours dropped 16 percent to 8,701,000. The decline was caused by scaling down of the GI Flight Training Program and changes enacted by the Congress to make it more difficult for veterans to qualify for flight training. Flight training activity continued to drop in the succeeding years. In the 1950s and early 1960s, annual instructional hours dropped to less than 2 million hours.

The fluctuation trends of instructional flying since 1962 are shown in Figure 1, page 12. Between 1962-1965, the annual flight hours averaged about 2.7 million; from 1966 to 1990, annual flight hours fluctuated between 5 to 8 million hours a year, accounting for about 18 percent to 25 percent of total general aviation flight hours.

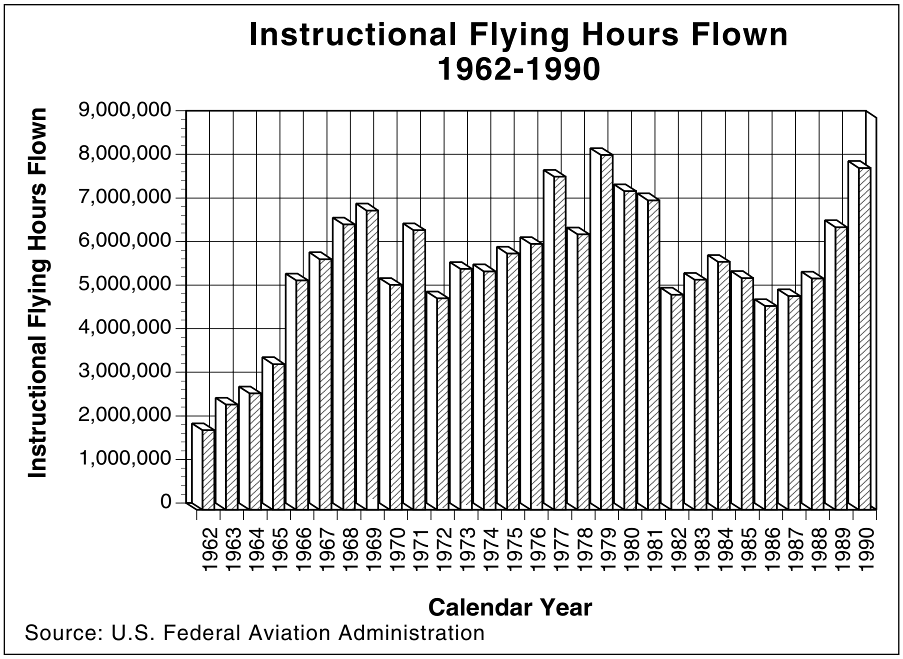


Figure 1

the increase or decrease of instructional flight time and the issuance of new certificates and ratings are closely related. In general, as the annual issuance of new certificates and ratings increases, instructional flight time increases correspondingly. However, during the past 10 years, annual student pilot certificates issued (Figure 3, p. 13) shows a declining trend. Therefore, the increase of annual new pilot and commercial pilot certificates as well as additional ratings issued since 1986 is primarily attributed to an increase in private pilot and commercial pilot certificates.

New Pilot Certificates and Ratings Related to Instructional Flight Hours

The annual issuance of new pilot certificates and additional ratings since 1962 is shown in Figure 2. A comparison of the annual flight time as shown in Figure 1 and of new certificates issued as shown in Figure 2 reveals that

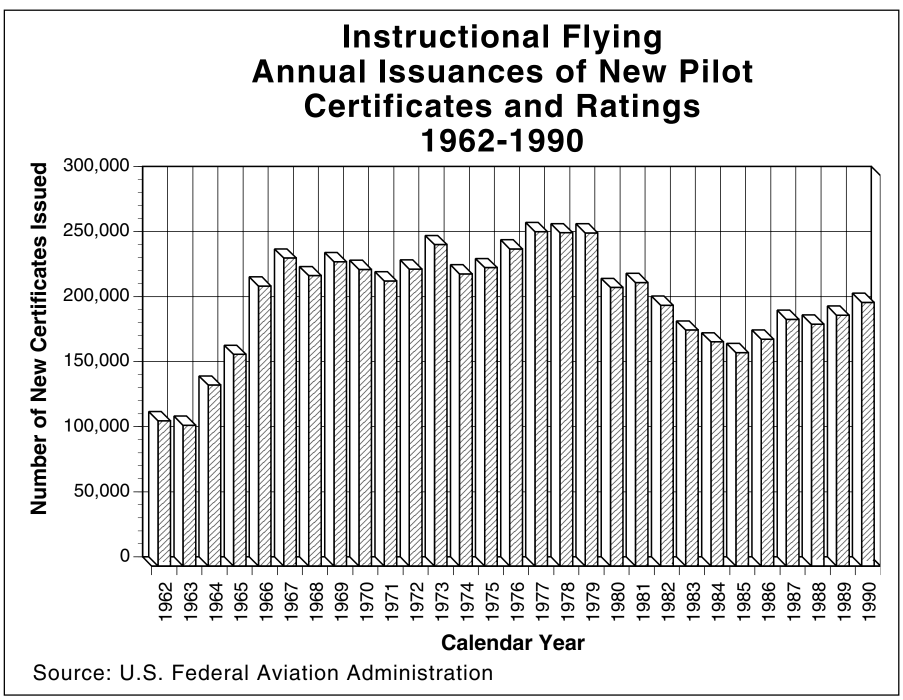


Figure 2

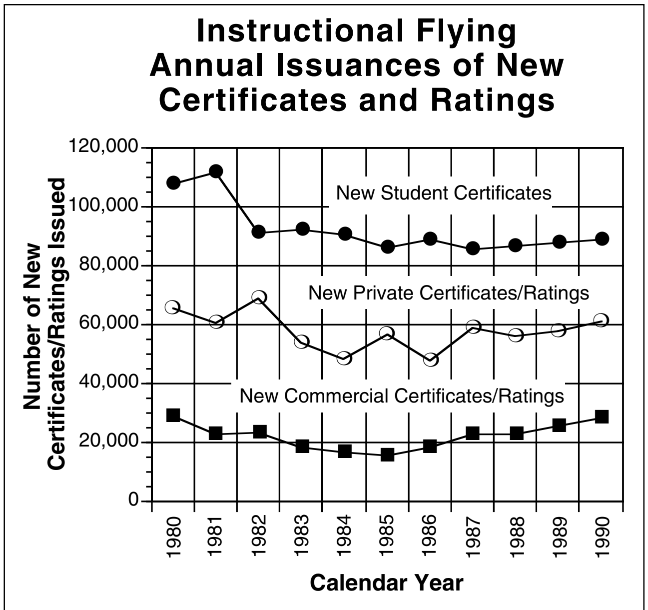
Aircraft Used for Instructional Flying

Figure 4 (page 13) shows the instruction hours flown by aircraft type for the past 10 years. In general, more than 90 percent of the aircraft used for training flights are single-engine, piston-powered aircraft followed by twin-engine, piston-powered aircraft (4 percent); rotorcraft (3 percent); gliders (2 percent). Turboprop and turbojet aircraft accounted for less than one percent of total instructional time.

Instructional Flying Remains Relatively Safe

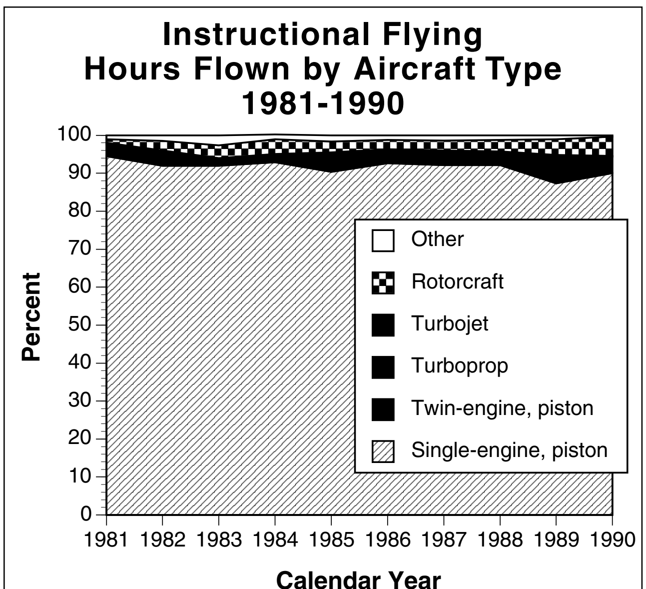
Figures 5 and 6 (page 13) show total accident rates and fatal accident rates per 100,000 hours for the 25-year period 1965 to 1990. Note that total accident rates are steadily declining. Fatal accident rates fluctuated significantly, particularly during the past 10 years.

Table 1 (page 14) lists the total accident and fatal accident rates of general aviation and those for instructional flying for the years 1981-1990. The comparison shows that in the past decade total accident rate and the fatal accident rates of general aviation flying are much higher than those for instructional flying. In other words, instructional flying is relatively safe compared with overall general aviation flying.



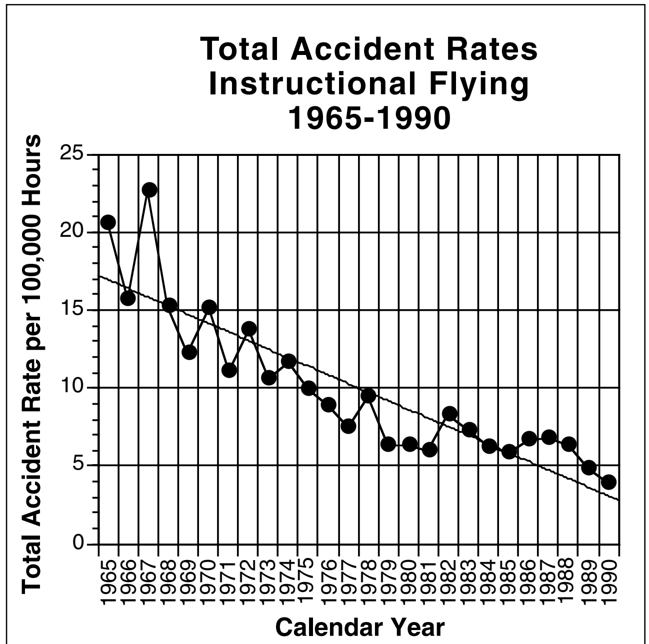
Source: U.S. Federal Aviation Administration

Figure 3



Source: U.S. Federal Aviation Administration

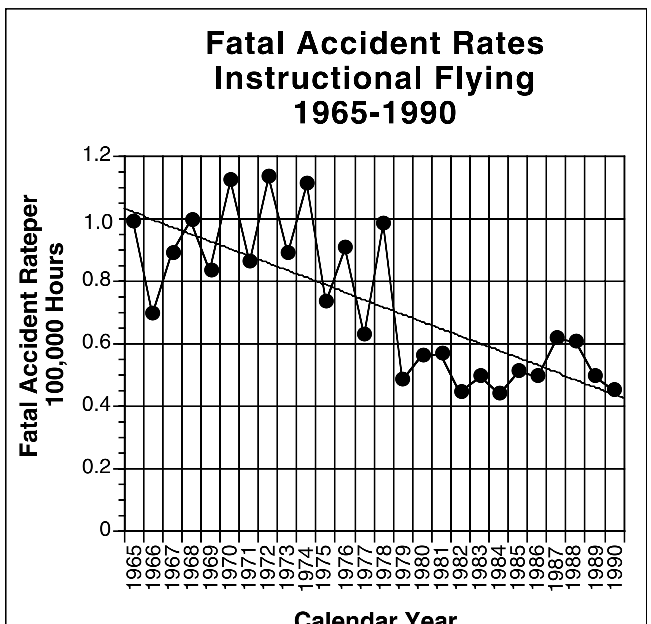
Figure 4



Source: U.S. Federal Aviation Administration

Figure 5

An analysis of accidents involving instructional flying by cause/factor for the 1980-1986 period is shown in Table 2 (page 14). The statistics show that the distribution of accident cause/factors through the years has changed very little. Similar to other types of general aviation flying, the pilot was a cause/factor in



Source: U.S. Federal Aviation Administration

Figure 6

Table 1
Total Accident and Fatal Accident Rates*
General Aviation All Operations vs. Instructional Flying
1981-1990

Year	General Aviation Accident Rate Per 100,000 Aircraft Hours Total	Fatal	Instructional Flying Accident Rate Per 100,000 Aircraft Hours Total	Fatal
1981	9.51	1.78	6.02	.56
1982	10.06	1.84	8.32	.45
1983	9.90	1.79	6.51	.44
1984	9.55	1.72	6.20	.44
1985	8.94	1.62	5.90	.51
1986	8.79	1.61	6.71	.49
1987	8.43	1.47	6.87	.61
1988	7.99	1.53	6.34	.60
1989	7.32	1.40	4.80	.51
1990	7.08	1.41	3.90	.44

* Preliminary data.
Source of estimate: U.S. Federal Aviation Administration.
All operations other than those conducted under Federal Aviation Regulations Parts 121 or 135.
Accidents on foreign soil and in foreign waters are excluded.
Suicide and sabotage accidents excluded from rates as follows:
All accidents- 1982 (3), 1983 (1), 1984 (3), 1985 (3), 1987 (1), 1988 (1), 1989 (3)
Fatal accidents - 1984 (2), 1985 (2), 1987 (1), 1989 (2)

Source: U.S. Federal Aviation Administration

Table 2
Broad Cause/Factor Assignments in All Accidents
Instructional Flying
1980-84 and 1985-86

Broad Cause/Factor	1980-1984 Mean	1980-1984 Percent	1985-1986 Mean	1985-1986 Percent
Pilot	357.6	87.3	287	90.5
Terrain	91.0	22.2	74	23.3
Weather	89.0	21.7	63	19.9
Miscellaneous	54.6	13.3	30	9.5
Powerplant	48.8	11.9	48	15.3
Personnel	41.6	10.2	39	12.3
Landing Gear	30.0	7.3	19	6.0
Airport/Airways/Facilities	27.6	6.7	29	9.1
Undetermined	15.0	3.7	7	2.2
Systems	4.0	1.0	4	1.2
Airframe	3.2	.8	3	1.0
Rotorcraft	2.4	.6	1	
Instruments/Equipment/ Accessories	1.6	.4	7	2.2
Total Aircraft	409.6		317	

Source: U.S. Federal Aviation Administration

Table 3
Instructional Flying
Phase of Operation for Accident-Involved Aircraft
1976-1986

Phase of Operation	1976-80 No.	1976-80 Percent	1981-84 No.	1981-84 Percent	1985-86 No.	1985-86 Percent
Approach/Landing	320	58.8	280	58.5	173	54.6
In Flight	105	19.3	70	17.0	64	20.2
Takeoff/Climb	95	17.5	80	19.5	68	21.4
Taxi	17	3.1	14	3.4	6	1.9
Static	5	0.9	3	0.7	4	1.3
Other	2	0.4	3	0.7	2	0.6
Total	544	100.0	450	99.8	317	100.0

Source: U.S. Federal Aviation Administration

almost 90 percent of all accidents, followed by terrain, 22 percent and weather, 20 percent. Powerplant and landing gear were also cited in one-fifth of the accidents.

Table 3 shows instructional accidents by phase of operation between 1976-1980, 1981-1984 and 1985-1986. The statistics show that in every period, about 55 percent of the accidents occurred during approach/landing, 20 percent during takeoff/initial climb and another 20 percent during cruise.♦

Reports Received at FSF Jerry Lederer Aviation Safety Library

Reports

Air Traffic Control Specialists in the Airway Science Curriculum Demonstration Project, 1984-1990: Third Summative Report. Final Report/Dana Broach (Civil Aeromedical Institute). Washington, D.C. U.S. Federal Aviation Administration, Office of Aviation Medicine; Springfield, Virginia, U.S. Available through the National Technical Information Service*, [1991]. Report No. DOT/FAA/AM-91/18. 20 p. : charts.

Key Words
1. Aeronautics — Study and Teaching (Higher) — United States.
2. Air Traffic Controllers — Selection and Appointment — United States.
3. United States — Federal Aviation Administration — Officials and Employees — Selection and Appointment.

Summary: The objective of this summative evaluation of the Airway Science Curriculum Demonstration Project (ASCDP) was to compare the performance, job attitudes, retention rates and perceived supervisory potential of graduates from recognized airway science programs with those of individuals recruited through traditional means in the air traffic control Specialist (ATCS) occupation. Previous evaluations…described institutional and organization benefits that accrued to the agency, participating institutions and industry. In this technical evaluation, differences between airway science-hires and a random, stratified sample of traditional ATCS-hires on eight program objectives were evaluated according to: interest in an aviation-related career; attrition; technical competence; attitudes toward technological change; managerial potential; human relations skills; female and minority representation; and perceptions of the FAA. Controllers hired from the airway science register expressed significantly more interest in an aviation-related career. There were no significant differences between traditional-hires and airway science hires on the remaining criteria. Overall, the performance of airway science hires was about the same as that of traditionally-hired controllers. [Abbreviated author abstract]

Human Factors in Aviation Maintenance : Phase 1, Progress Report / William T. Shepherd … [et al.]. Washington, D.C. U.S. Federal Aviation Administration, Office of Aviation Medicine; Springfield, Virginia, U.S. Available through the National Technical Information Service*, [1991]. Report No. DOT/FAA/AM-91/16. x, 158 p. : charts.

Key Words
1. Aeronautics — Human Factors.
2. Airplanes — Maintenance and Repair.
3. Aviation Mechanics (Persons) — Psychology.

Summary: This human factors research in aviation maintenance addresses four tasks including studies of organizational behavior, job and task analysis in maintenance and inspection, advanced technology for training, and the application of job training to maintenance. The first phase of a three-phase research program describes extensive preliminary investigation of airline maintenance practices. Each chapter describes the Phase I investigation and problem definition followed by the plan for the Phase II demonstrations.

Engine Bird Ingestion Experience of the Boeing 737 Aircraft: Expanded Data Base (October 1986-September 1989)/ [Peter W. Hovey, Donald A. Skinn and Joseph J. Wilson] Atlantic City International Airport, N.J., U.S. Federal Aviation Administration Technical Center; Springfield, Virginia, U.S. Available through the

National Technical Information Service*, [1992]. 196 p. in various paging: charts. Includes glossary and bibliographical references (p. 96-97).

Key Words
1. Bird Pests.
2. Airplanes — Turbojet Engines — Blades.
3. Aeronautics — United States — Accidents.
4. Boeing 737 (Jet Transport).

Summary: The FAA Technical Center (Atlantic City, N.J.) initiated a study in October 1986 to determine the numbers, weights and species of birds that are ingested into medium- and large-inlet turbofan engines and to determine what damage, if any, results. This final report provides descriptive and statistical analyses of the data collected over a three-year period on bird ingestion experiences for Boeing 737 aircraft that use either the Pratt & Whitney JT8D medium-inlet turbofan engine or the CFM International CFM56 large-inlet turbofan engine. This report updates the data collected by the engine manufacturers and the FAA with that from the International Civil Aviation Organization (ICAO) during the period from October 1986 through September 1989. [Modified Abstract]

Aircraft Accident Report: L'Express Airlines, Inc., Flight 508 Beech C99, N7217L Weather Encounter and Crash Near Birmingham, Alabama, July 10, 1991/ National Transportation Safety Board (NTSB). Washington, D.C. U.S. National Transportation Safety Board; Springfield, Virginia, U.S. Available through the National Technical Information Service*, 1992. Report No. NTSB/AAR-92/01.vi, 138 p.: ill., maps. Includes appendices and radar study.

Key Words
1. Aeronautics — Alabama, Birmingham — Accidents.
2. Aeronautics — Accidents.
3. Beechcraft (Airplanes) — Accidents.

Summary: On July 10, 1991, L'Express flight 508 (LEX508) crashed in a residential area southwest of Birmingham, Alabama, U.S., while conducting an instrument landing system (ILS) approach to runway 5 at the Birmingham Airport (BHM). LEX508 was a Beech C99 on an instrument flight rules (IFR) flight. The airplane was destroyed by the impact and the postcrash fire. Two homes were destroyed. The captain and one passenger survived the crash while the first officer and the remaining 12 passengers aboard were fatally injured.

The NTSB concluded that weather was a factor in the accident and the meteorological event that led to the accident was contained within a small geographical area and lasted only minutes. The flight crew was aware of the possibility of thunderstorm activity in the Birmingham area. As LEX508 approached BHM, several airplanes were also in the vicinity and attempting to land at the airport. Three of these airplanes diverted to other locations because of thunderstorms around the airport. Two others landed successfully at BHM (one prior to the accident and one after it).

The NTSB determined that the probable cause of the accident was the decision of the captain to initiate and continue an instrument approach into clearly identified thunderstorm activity resulting in a loss of control of the airplane from which the flight crew was unable to recover and subsequent collision with obstacles and the terrain. As a result of its investigation, the NTSB issued three Class II, Priority Action recommendations: A-92-18, A-92-19 and A-92-20. In addition, NTSB reiterated recommendation A-91-93 to the FAA.[Modified Report and Findings] ♦

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National Technical Information Service (NTIS)
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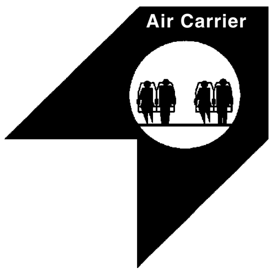
Gaithersburg, MD 20877 U.S.
Telephone: (202) 275-6241

Accident/Incident Briefs

This information is intended to provide an awareness of problem areas through which such occurrences may be prevented in the future. Accident/incident briefs are based upon preliminary information from government agencies, aviation organizations, press information and other sources. This information may not be entirely accurate.



Cockpit Electrical Fire Forces Emergency Descent

Boeing 737-300. Minor damage. No injuries.

The Boeing 737-300 was climbing to cruise altitude 10 minutes after takeoff when the cockpit crew heard an electrical arcing sound and detected a faint burning odor.

The lead flight attendant was contacted and she reported hearing the sound but did not smell anything. It was later determined that cabin lights flickered and the galley oven cycled briefly. The cockpit crew determined that all circuit breakers were closed while the flight attendant checked the cockpit overhead panels. The electrical fire checklist was run, but no faults were detected.

The flight was cleared to FL370 (37,000 feet). But as the aircraft passed FL330 (33,000 feet), a loud arcing sound was heard and accompanied by a yellow flash, flame and black smoke from the overhead panel at the cockpit door. The first flight attendant discharged a halon extinguisher on the exterior of the panel and the captain declared an emergency, entering a descending turn back to the departure airport. A second flight attendant used the cockpit axe to pry open the panel and discharged a second extinguisher directly on a charred wire bundle. The aircraft landed without further incident and there were no injuries.

A U.S. Federal Aviation Administration airworthiness directive was issued based on a post-flight examination that determined that the wire bundles were positioned in a manner that allowed chaffing on the overhead frame of the cockpit door. The shorted wire bundles fed power to the galley.

Poor Visibility, Faulty Clearances Cause Near-collision on Runway

Boeing 727. No damage. No injuries.

The Boeing 727 was cleared to taxi to runway 01L, and advised by ground control to follow a BAe-146. While taxiing, the Boeing 727 lost sight of the BAe-146 in the darkness and fog. At taxiway Hotel, the B-727 crew saw the red runway end lights, turned onto Hotel and held. The Boeing crew told the tower they were on frequency.

The tower then cleared the BAe-146 for takeoff and cleared the Boeing 727 onto the runway to hold. As the 727 started rolling forward, the captain glanced to the right and saw four aircraft lights accelerating down the runway toward him. He quickly applied the brakes. The BAe-146's wingtip passed the 727's nose at an estimated distance of 15 feet.

A subsequent inquiry determined that the BAe-146 entered the runway for takeoff at taxiway Mike, which is about 500 feet south of the runway end markers. This taxiway segment was used as a displaced landing threshold, usable for takeoffs on runway 01L.

The tower controller, when issuing clearances, had assumed that both aircraft were at taxiway Mike.

As a result of the incident, the tower changed procedures for issuing clearances during times of low visibility when controllers cannot see the runway. Clearances now include the active runway designator and the taxiway designator for the expected runway entry point. Pilots have also been asked to request a designated runway entry point if one is not issued by a controller.

Locked Rudder Pedals Leave First Officer Without Control

Boeing 757. No damage. No injuries.

During approach and landing rollout, the first officer's rudder pedals jammed.

Rudder control of the Boeing 757 was transferred to the captain, who was able to kick the pedals free and regain full control.

An investigation determined that there was interference between the first officer's left rudder pedal and the top of the rudder pedal cover installation bottom panel. The problem was solved by eliminating material from the panel to keep the top of the rudder pedal from jamming.

Air Taxi
Commuter

Loose Trim Tab Leads to Bumpy Approach

Fairchild FH227. Substantial damage. No injuries.

In level flight at FL150 (15,000 feet), with the autopilot engaged, the aircraft and control column began to vibrate. When the autopilot was disengaged, the aircraft began to climb and the vibrations stopped.

An attempt to trim the nose down was unsuccessful. When the airspeed dwindled below 150 knots, the vibrations increased again. Descent, approach and landing were completed at more than 150 knots with no flaps.

An investigation determined that the elevator trim actuating jack was loose, allowing the trim tab to move freely at the trailing edge of the elevator.

Hot Tailwind Landing Yields Predictable Outcome

Yakovlev Yak-40. Substantial damage. No injuries.

The YAK-40, on a Russian domestic flight, attempted a tailwind landing, although the approach was too high and too fast.

The aircraft, with 31 passengers and a crew of four aboard, overshot the runway and rolled into a gully. An evacuation was completed without incident. There were no injuries.

Steep Climb Ends in Tragedy

Lockheed Harpoon/PV-2. Aircraft destroyed. Eight fatalities.

The aircraft made three low passes over seaplanes anchored at a California (U.S.) seaplane base.

On the fourth pass, the aircraft’s climb was much steeper. The aircraft rolled at the apex of the climb and entered a steep dive, crashing into the lake.

Seven passengers and the pilot were killed in the daylight accident. Weather was not a factor.

Corporate Executive

Control Loss on Approach Ends in Tragedy

Beech 90 King Air. Aircraft destroyed. Three fatalities.

The King Air pilot was on final approach for a daylight landing when the aircraft yawed suddenly to the right 25 degrees and back to the left at an altitude of 70 feet above ground level.

The aircraft failed to recover and contacted the ground in a 45-degree left bank. The aircraft was destroyed by impact and a fierce post-crash fire. The crew of two and a passenger were killed in the accident.

Ice Keeps Cessna Down

Cessna 414. Aircraft destroyed. No injuries.

The Cessna's daylight initial take-off run was normal, but the aircraft failed to gain sufficient speed. The pilot aborted the takeoff and the aircraft overran the runway and struck trees and terrain. The pilot and three passengers managed to evacuate the aircraft without injury.

An investigation determined that the aircraft was coated with ice before takeoff and was at maximum gross weight.

Fast Approach Sends Baron Skidding

Beech 58 Baron. Substantial damage. No injuries.

During the daylight approach, the pilot realized that he was too high and too fast but continued anyway, touching down late. After the brakes were applied, the aircraft skidded and the tires failed. The Beech overran the runway, plowed through a fence and came to rest in a field with the right main gear and nose gear collapsed.

Other General Aviation

Midair Collision Claims Four Lives

Tigermoth. Piper PA28. Both aircraft destroyed. Four fatalities.

The Tigermoth was departing a rural airport in a steep climb when it collided with the Piper, which was descending to join the pattern for a daylight approach.

Radar traces indicated that the aircraft were on a collision course for some time and that the cause of the collision was failure on the part of both pilots to adequately monitor pattern traffic. The pilot of the Tigermoth was killed, along with a crew of two and one passenger aboard the Piper.

Aerobatic Maneuver Goes Awry, Kills Two

Cessna 150. Aircraft destroyed. Two fatalities.

As the aircraft approached the end of the runway at about 100 feet, the pilot applied full power and pulled into a vertical climb.

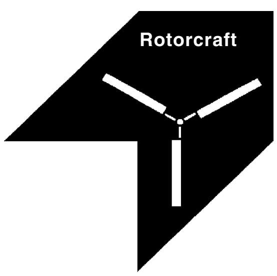
At the top of the climb (estimated between 300 and 400 feet), the engine noise ceased and the aircraft executed a stall to the right. The power increased and the nose began to rise, but the aircraft rolled quickly to the left and hit the ground at approximately a 30-degree vertical angle. The pilot and passenger were killed by impact and a post-crash fire. An investigation found no mechanical problems that could have contributed to the crash.

Navigation Error Ends in Forced Landing

Cessna 152. Aircraft destroyed. No injuries.

The private pilot, with a total flight time of 99 hours, embarked on a daylight cross-country flight. However, the pilot misread visual cues and the aircraft began running low on fuel.

The fuel shortage became critical after several unsuccessful attempts to locate a suitable airport. A precautionary landing was initiated in a ploughed field. The aircraft touched down satisfactorily, but the nose wheel dug in and the aircraft flipped over.



Emergency Medical Flight Crashes on Highway

MBB BK117. Aircraft destroyed. One fatality. Two serious injuries.

The helicopter was entering a landing zone at night when it struck power lines. The impact sheared the tail rotor, and the aircraft crashed on a highway.

The impact killed one crew member and seriously injured the pilot and another crew member.

Weather at the time of the accident was reported to be visual meteorological conditions, although some fog was present in the area.

Tail Rotor Strike Results in Forced Landing

McDonnell Douglas MD 500D. Aircraft destroyed. No injuries.

The aircraft landed in daylight on an unstable surface at a mountaintop site.

The pilot said that he and a front-seat passenger exited the helicopter during the shutdown phase, while the main rotor blades were winding down. The helicopter rocked back and the tail rotor struck the ground. Subsequent examination of the rotor and connecting drive train showed no damage, so the pilot elected to fly the aircraft.

Three minutes after departing the mountaintop, the pilot felt a severe vibration followed by a loss of tail rotor thrust. The pilot said that he was unable to control the aircraft and was forced to make an emergency landing in a lake. The helicopter sank in 30 feet of water. The pilot and three passengers escaped uninjured.♦