Study Urges Application of Flight Operational Quality Assurance Methods In U.S. Air Carrier Operations

The Flight Safety Foundation has completed a pivotal study on the requirements, costs and implementation issues involved in setting up flight operational quality assurance programs at U.S. airlines. More than 25 non-U.S. airlines that have adopted such programs were contacted.

—

by
John H. Enders, Vice Chairman
Flight Safety Foundation

Editor's Note: *The Flight Safety Foundation (FSF) recently submitted a final 252-page report,* "Air Carrier Voluntary Flight Operational Quality Assurance Program," *to the U.S. Federal Aviation Administration (FAA), concluding a 16-month contract with the agency.*

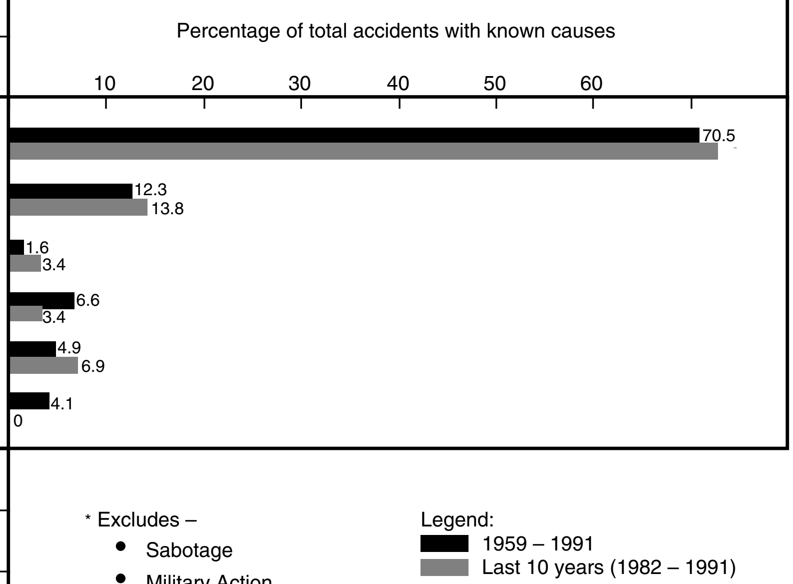
The contract objectives were to conduct a study of current air carrier usage of on board data collection and analysis, and to prepare a report on flight operational quality assurance (FOQA) program requirements, associated costs and implementation concerns. The study report examines current practices of airlines with FOQA programs and, based on these practices, develops technical and management information to guide in voluntary FOQA implementation.

During the past 15 or 20 years, growing recognition of the important role that human error plays in establishing trends that may lead to airplane accidents has prompted much more attention to understanding how accidents and incidents develop.

Analysis of primary causal factors in air carrier hull-loss accidents reveals that flight crew performance is often cited as a primary factor in these accidents (Figure 1, page 2).

Primary Cause Factors — Hull-loss Accidents*
U.S. Commercial Jet Fleet

Primary factor	Number of Accidents: Total	Number of Accidents: Last 10 years
Flight crew	86	21
Airplane	15	4
Maintenance	2	1
Weather	8	1
Airport/ATC	6	2
Miscellaneous/other	5	0
Total with known causes	122	29
Unknown or awaiting reports	9	5
Total	131	34



* Excludes –
- Sabotage
- Military Action

Source: Boeing Commercial Airplane Group

Figure 1

Many causes attributed to flight crews have their origins elsewhere: (e.g., maintenance or management), manufacturer's designs that enable the crews' actions, and system errors (e.g., air traffic control (ATC) conflicts, inaccurate weather information, etc.). A program that focuses on the total scope of operational irregularities that may occur as a result of human actions throughout the system should be able to identify remedial actions that could contribute to the further improvement of safety.

Looking at the accident record according to the phase of flight, it is evident that the vast majority (about 80 percent) of the accidents occur at low altitudes and on runways during takeoff and approach/landing phases that account for about 17 percent of the average total mission time (Figure 2, page 3).

To maintain a perspective on air carrier accidents, it is necessary to note that the U.S. airline accident rate improved rapidly during the 25 years immediately following World War II, but after that period leveled out to a low, but fairly constant, rate that continues today (Figure 3, page 4). While travel risks by air are low in comparison with many other common human activities and other forms of transportation, accidents that do occur are frequently found to have been preventable, if all relevant factors had been known and acted on.

Because of this long-term steadying of the accident rate, one can assume that it will not change substantially without a new approach to accident prevention. Despite the current state of the economy, there is still confidence that the air transport industry will continue to grow, with more flights, more aircraft and more passengers. Thus, without an improvement in the accident rate, the absolute number of accidents will increase, leading to greater losses and a consequent loss of confidence in air travel safety (Figure 4, page 5).

One means of identifying factors that can be better controlled to reduce accidents and serious incidents is the use of flight data recorder

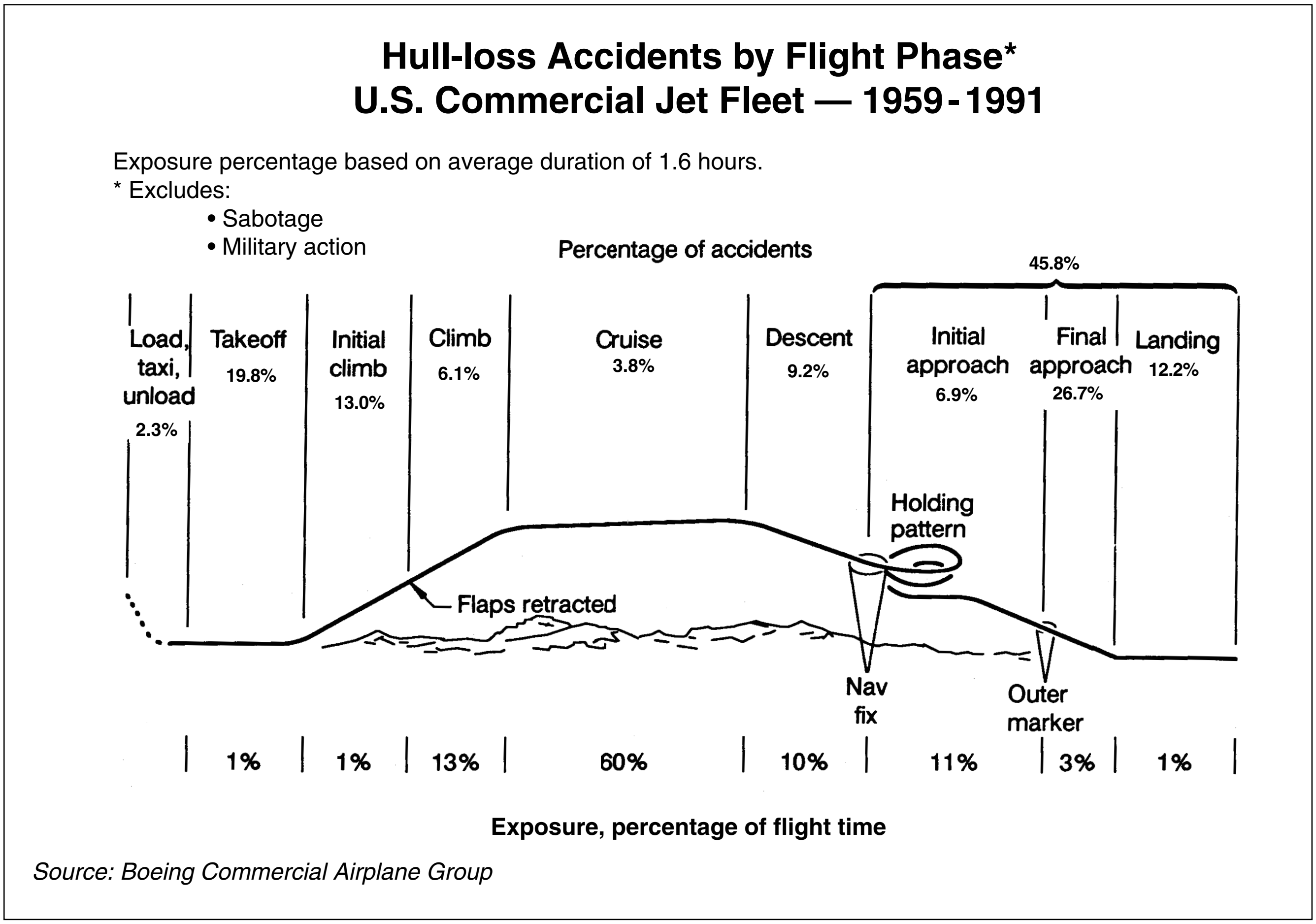


Figure 2

(FDR) capability in a FOQA program that provides reliable data. This in turn helps in making decisions about product and procedural changes in the interests of safety improvement.

Some 25 or more non-U.S. air carriers have some form of FOQA program to analyze the safety quality of their operations and to detect subtle or insidious trends that can creep into daily operations. In numerous cases, the detection of slight exceedances of flight parameters (e.g., descent rates, airspeeds, etc.) enabled operational managements to take action through such measures as information dissemination, training emphasis, ATC procedures changes, etc., to break the chain of events that frequently accompany such trends and set the stage for an accident or serious incident.

The air transport industry's long-established practice of discovering, understanding and eliminating factors that lead to accidents and incidents has been the major determinant in an impressive reduction of the civil air transport accident rate since the mid-1940s.

FDRs have been used for many years in accident investigations and inflight structural loads measurement programs, and have provided much of the information that has helped identify accident causes. Nevertheless, one element missing from the analyses of accidents, incidents and other events has been comprehensive, quantitative and objective information about operational irregularities and trends.

Technology now provides the means to collect and analyze a wider range of data. With the rapid growth of data collection and processing capabilities, flight data analysis has evolved rapidly during the past decade. Technologies presently used include FAA-mandated digital flight data recorder (DFDR) systems, airplane and engine condition monitoring, on board data storage hardware and software,

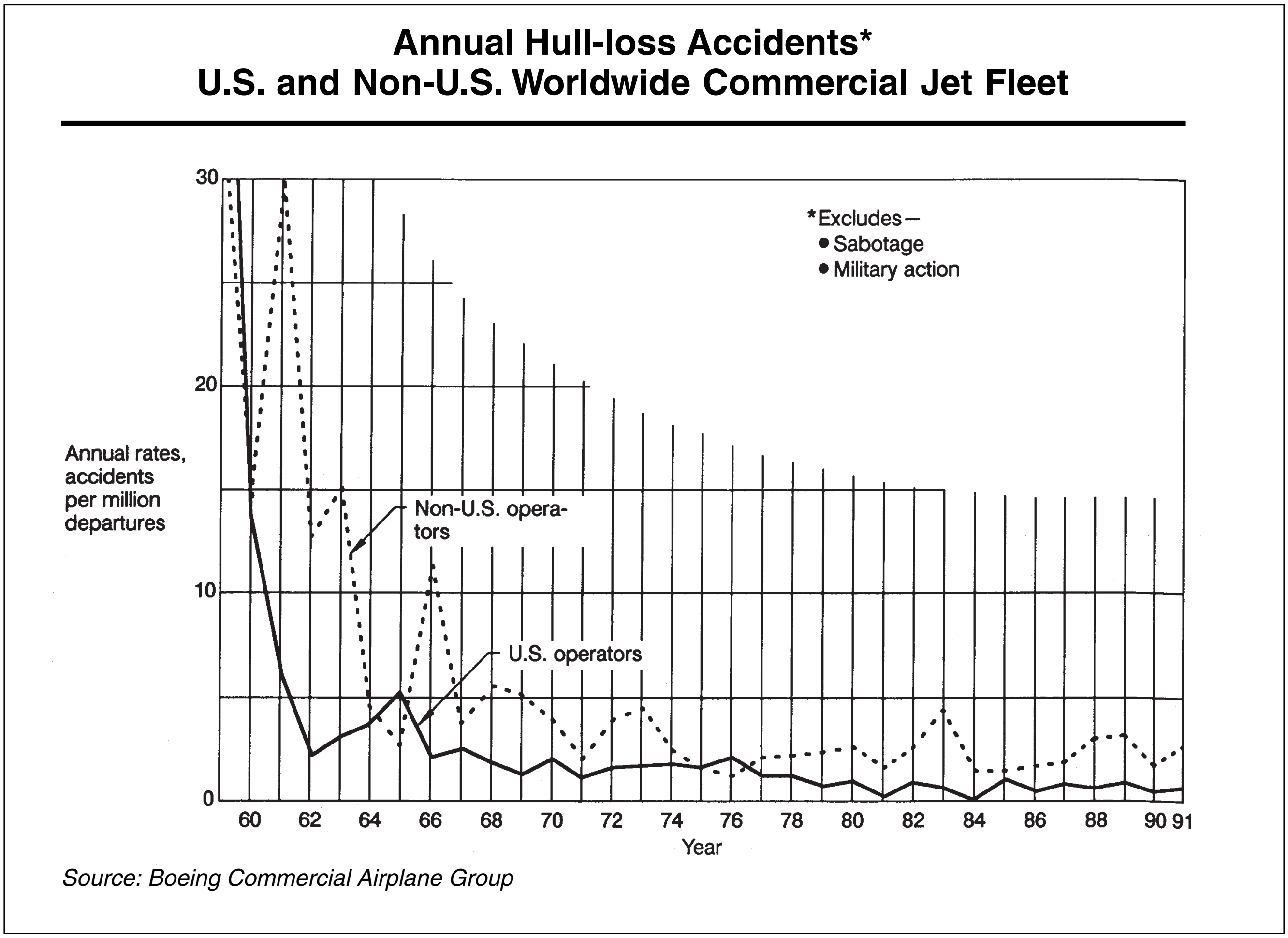


Figure 3

air/ground data links and personal computer (PC) data processing capabilities.

Following a series of FSF international seminar papers during the past decade and two recent special workshops devoted to examining the usefulness of FDR trend analysis, FSF and its International Advisory Committee (IAC) concluded that the benefits attributed to properly-established FDR (or FOQA) analysis programs by user airlines should be brought to the attention of a broader air carrier audience, particularly in the United States, where the threat of liability or punitive actions against both companies and pilots has hampered otherwise beneficial safety information transfer.

The concern by U.S. airlines and pilots is not ill-founded. As the litigiousness of U.S. society has increased, more and more professionals find themselves at increased risk of litigation and thus limit the sharing of information that would be collectively useful because of the threat that it could be used as potential evidence of misfeasance by those taking legal action for alleged damages.

In great part because of the FSF-IAC two-day workshop in Washington, DC in 1991, Air Transport Association of America (ATA) member airlines, aircraft manufacturers and the FAA recognized the role that FOQA might play in improving operational flight safety. Other cooperative industry and government programs are in place to address additional accident causes. Government and the aviation industry have adopted major programs aimed at enhancing human performance in all facets of aviation, and FOQA programs can add greatly to their effectiveness.

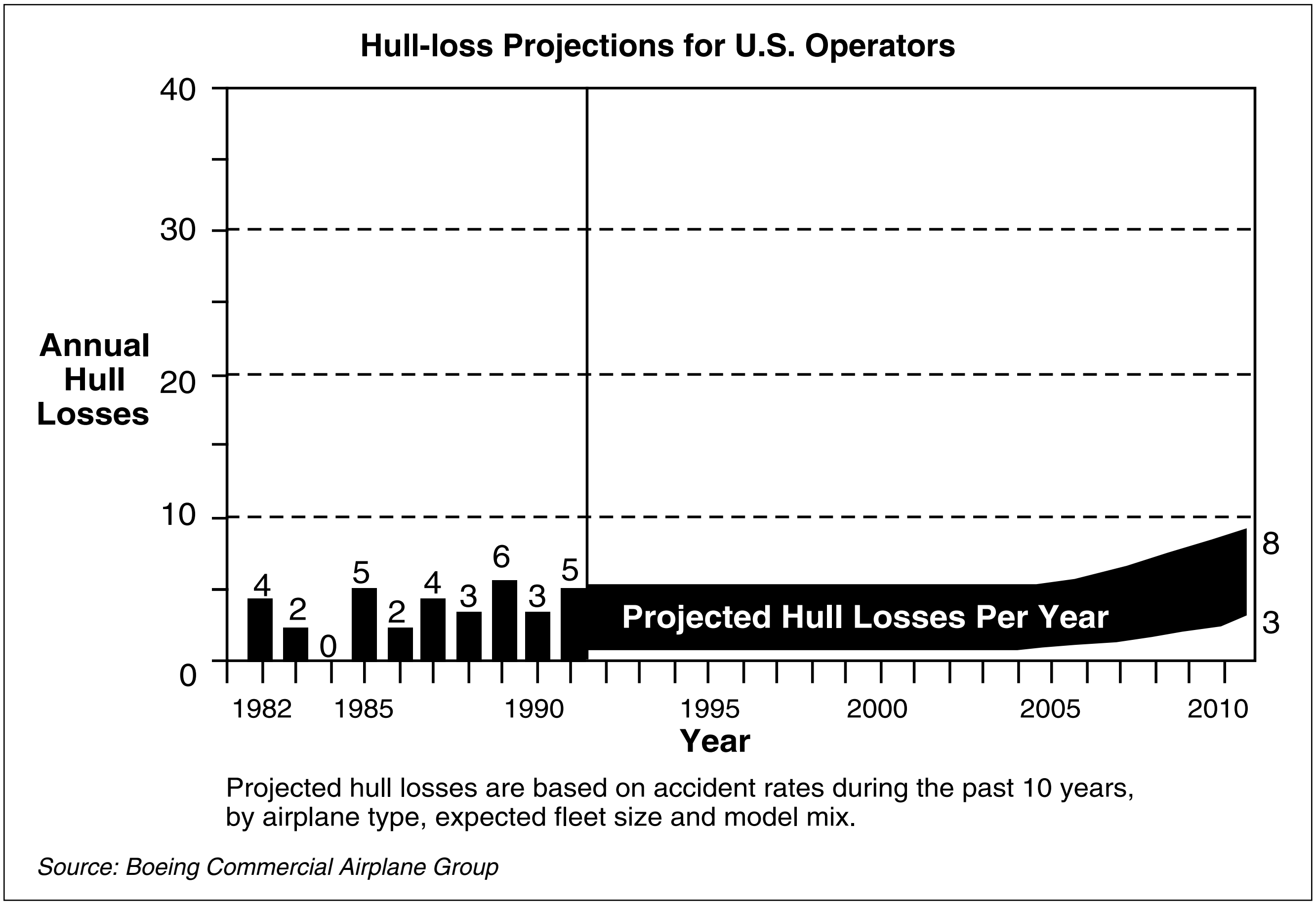


Figure 4

Operational Information Remains Key to Preventing Accidents

Throughout aviation history, analysis of accident investigation data has been a primary source of feedback to manufacturers and operators to improve safety by product and process modification.

It is a logical and desirable feature of systems that continuous safety improvement must make use of operational information of both successes and failures. Accident investigations yield much quantitative information. This information, taken together with the expert opinions of skilled and experienced investigators, can provide recommendations that organizations can depend on at a sufficient confidence level to justify the investment of the fiscal, material and human resources in product and procedural changes that will lessen the likelihood of an accident or incident.

Realizing that incidents are frequently the precursors of accidents, the aviation community has been frustrated by an inability to systematically and comprehensively discover incidents that might reveal a pattern by man or machine leading to a potential accident.

A major step forward was taken nearly 20 years ago with the establishment of the voluntary Aviation Safety Reporting System (ASRS), operated for the FAA by the U.S. National Aeronautics and Space Administration (NASA). The ASRS has permitted, on a confidential basis, the sharing of personal experiences that have compromised safety. In many cases the mere sharing of these incidents has raised the awareness levels of peer aviators and controllers, with a consequent, but undetermined, reduction of risk. The ASRS has yielded much useful information that has been factored into improved training of aviators and controllers, and into airspace and air traffic procedure modifications. One example of great significance was the usefulness of incident information concerning runway incursions in ground operations.

The advent of newer, miniaturized electronic on board FDRs has brought the ability to monitor aircraft systems for more effective and efficient maintenance.

More than 25 years ago, the U.K. Civil Aviation Authority (CAA) established its data recording program (CAADRP), a pioneering effort that used the determination of certain threshold values for critical flight parameters to record exceedances in flight. Thus, the quantification of incident data began in a regular and rational way. The usefulness of this technique soon proved itself in identifying early indicators of erroneous actions caused by system faults, crew mistakes or design deficiencies. Corrective actions through training emphasis and changes in procedures or product could now be confidently made for accident preventive purposes.

A major feature and underlying requirement of all successful FOQA programs today is the confidentiality of information. Without protection of information, the parties involved in the cooperative effort (companies and pilots) would not accept a FDR analysis program, and a major tool for safety improvement would be lost.

Task Force Studied FOQA Implementation

Flight Safety Foundation used a FOQA Task Force, organized under Technical Projects Director Robert Vandel, to study FOQA implementation issues. This Task Force consisted of a contract team comprising five subcontractors and an industry team comprising representatives from eight air transport industry segments. The industry team acted as an advisory panel and assisted with specific tasks.

The industry team consisted of representatives from ATA, American Airlines, Delta Airlines, Northwest Airlines, United Airlines, Air Line Pilots Association (ALPA), Allied Pilots Association (APA), Boeing Commercial Airplane Group, McDonnell Douglas, FAA, ASRS, the National Transportation Safety Board (NTSB) and Aeronautical Radio Inc. (ARINC).

Although the study's focus was on FOQA implementation among U.S. carriers, the information developed and the conclusions reached are also broadly applicable to air carriers throughout the world.

The FSF study recognized two main applications of the information developed: (1) the subjects pertaining to an individual airline contemplating FOQA implementation and (2) the broader issues pertaining to a national air transportation system.

The study's first objective was to collect information on all aspects of current in-flight recording programs in the air carrier environment (Table 1). This information was collected from user airlines; airframe, engine and equipment manufacturers; and from U.S. airlines using maintenance data recording programs — all in a uniform format through selected on-site visits and questionnaires. This infor-

Table 1
FOQA Study Sources

ORGANIZATION	TOTAL CONTACTED	TOTAL VISITED
Present User Airlines	25	7
Airframe Manufacturers	6	2
Equipment Manufacturers	16	8
U.S. Airlines	35	0
Engine Manufacturers	3	0

Source: Flight Safety Foundation

mation, augmented by a comprehensive literature survey of data recording programs, provided a foundation of information on all aspects of FOQA.

The study examined both the technical and the information security aspects of FOQA. Technical aspects included the details of current FOQA programs in use among international airlines; past, present and emerging technologies in aircraft and data system equipment; engine data system programs; and fleet composition and recording system details. Cost data, where available, were also included.

Because information security is a critical issue to industry acceptance of FOQA, the approach was different for this part of the study.

Protection-of-Data Issue Examined Carefully

Acceptance of FOQA by the industry depends on the assurance that information will be handled with confidentiality.

Acceptance of FOQA within the operating industry depends on the assurance that information will be handled with confidentiality.

The air carrier's concerns center on the potential for increased accident liability and punitive actions by the FAA for rule infractions that might be revealed by open sharing of FOQA data. The pilot community's concerns center on punitive actions by airline management or by the FAA. Both air carriers and pilots are concerned that data may become public through the U.S. federal Freedom of Information Act (FOIA) if FOQA data are supplied to governmental authorities.

To deal with this critical and sensitive issue, FSF developed a special working group within the Task Force that (1) used information derived from questionnaires about information security, (2) identified the study objectives associated with information security, (3) developed the issues, legal and otherwise, requiring resolution, and (4) proposed a solution or course of action for each issue. This working group was formed under the direction of the ASRS representative of the Task Force and included representatives from ALPA, APA, ATA, FAA, non-union pilots (through ALPA) and FSF. The working group concluded that a new FAA policy on compliance and enforcement should reduce airline and flight crew concerns about use of FOQA data for other than safety and operational improvement purposes. The study also concluded that:

(a) The success of the FOQA program ultimately depends on integrity and trust between management and pilots.

(b) An airline management and pilot association agreement is a key element of success because it identifies critical procedures for use and protection of data.

(c) Data security within airlines that proceed with a FOQA program can be optimized by:

i. Adhering to stringent agreements with pilot associations.

ii. Strictly limiting data access to selected individuals within the company.

iii. Maintaining tight control to ensure that linking of flight crew names with their flight data records is done only when absolutely necessary, and that crew identification with a particular flight is severed as soon as possible.

iv. Ensuring that any operational problems are promptly addressed by management, resolved expeditiously and documented.

v. Destroying all identified data as soon as possible.

(d) Early participation of pilot associations in technical and other decisions promotes acceptance.

(e) Airlines without pilot unions should recognize the influence that a sudden announcement of a FOQA program might have on pilots if there is no preparatory action taken to enlist their support. A policy statement that supports a pilot and management agreement is recommended.

The study recognizes that the possession of FOQA data by federal government agencies makes it subject to provisions of the FOIA. Airline data therefore must be deidentified so that they cannot be connected with a specific air carrier. Deidentification will prevent inappropriate and misleading comparisons of airlines that could adversely and incorrectly affect public confidence in a particular carrier.

FOQA programs offer a wide range of applications for recorded flight data.

The study also concluded that the FAA's desire to use the data for safety assessments (advanced qualification program (AQP) training) and for other projects must be coupled with proper regulatory and, if necessary, legislative protection.

The data protection issues are so critical to the acceptance and success of FOQA that the study concludes that they must be resolved before the FAA releases an Advisory Circular on FOQA.

To this end, the study recommends that FAA vigorously address information protection issues. It recommended that the FAA:

(a) Continue the program begun by the FOQA Task Force to satisfy airline and flight crew concerns about appropriate flight operations data use.

(b) Require no data from any airline's FOQA program until airline and flight crew concerns about the appropriate use of the data are resolved.

(c) Convene an industry conference to discuss the FOQA study and future plans as soon as means for resolution of the data use and protection issue are developed.

FOQA Program Offers Many Benefits

FOQA programs offer a wide range of applications for recorded flight data. For the purposes of the study, FOQA was defined as:

> "A program for obtaining and analyzing data recorded in flight to improve flight crew performance, air carrier training programs and operating procedures, air traffic control procedures, airport maintenance and design, and aircraft operations and design."

In practice, a FOQA program is a subset of a total in-flight data system that includes engine, maintenance and aircraft systems monitoring. FOQA is, however, separately managed, has separate data requirements, specific hardware and software requirements (though some measurements and recording systems hardware may be shared) and is subject to a separate, more secure management process. Characteristics that exemplified the FOQA concept include:

- An independent management and organizational structure;
- A defined set of operational events that are monitored and analyzed for exceedance beyond established limits;
- An airborne recording system to record data associated with the operational events;
- Established data use, control and retention policies and procedures;
- Pilot association agreements relative to data use policies and procedures;
- Data playback and analysis facilities and software, and
- Formal data trend, feedback and action programs.

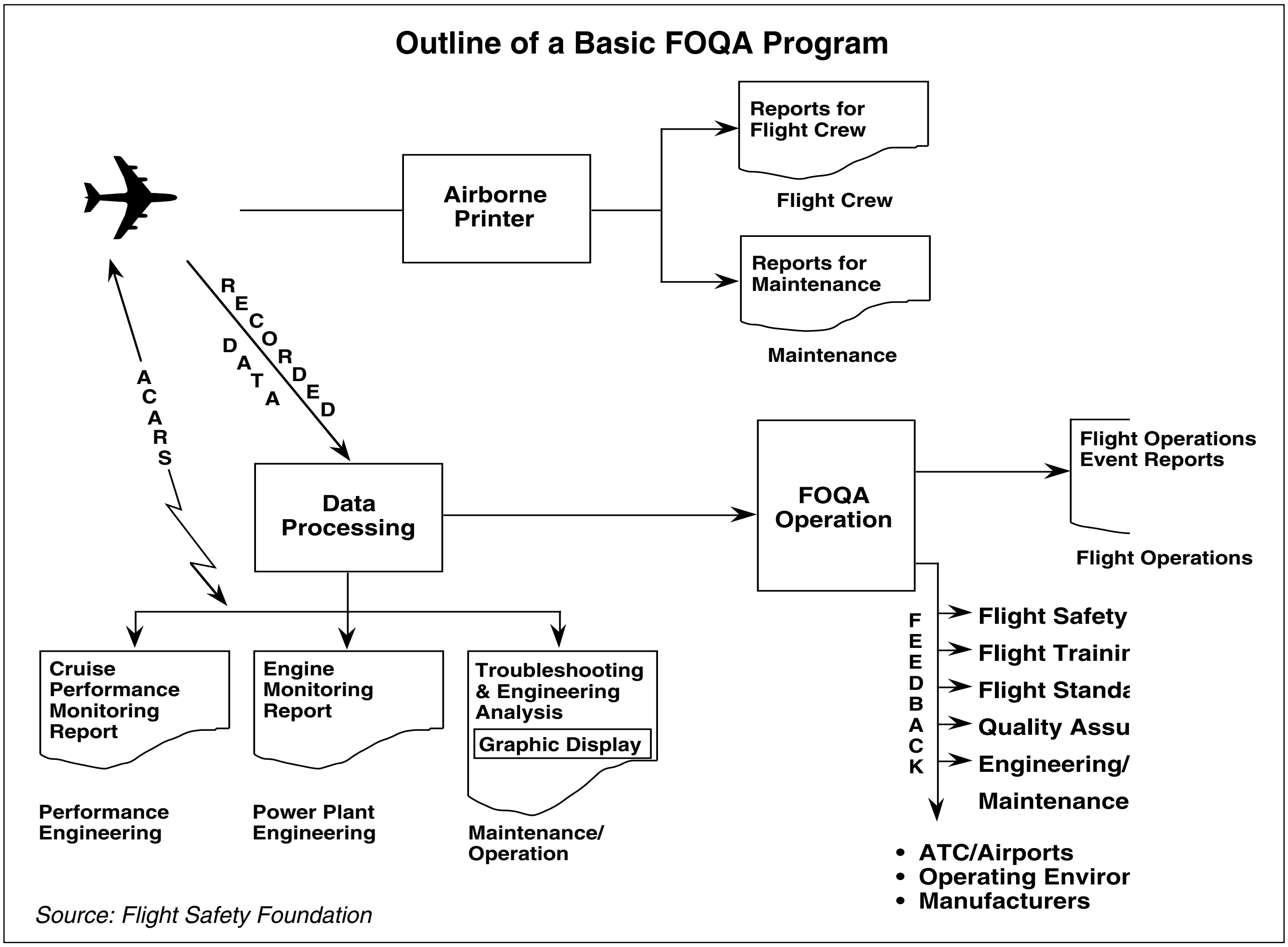


Figure 5

A FOQA program is made up of three major elements — airborne, ground and process systems (Figure 5). The airborne and ground systems include hardware and software elements. The process system supplies the methodology by which the data are produced, analyzed and protected.

The airborne system can have a variety of parts depending on the hardware choices made by the airline, the airplane data systems provided by the manufacturer and the systems that were added to the basic airplane either at the time of purchase or later. Regardless of the configuration, the basic purpose of the airborne hardware and software is to acquire (record) and store the data for later processing and analysis.

The ground system processes the recorded digital data into engineering units, performs analysis routines and produces the required formats and reports for analysis and action by the user.

The process system is divided into two elements: the operational processes needed to make the FOQA program function and the protection processes to ensure proper use of the data. Operating processes include those that enable the data system to produce the desired information. They also include management processes in which the information is evaluated and decisions made on what action should be taken, as well as feedback/followup measures to ensure that problems are resolved.

In all FOQA applications, particularly in high technology aircraft, the FOQA program relies on other data systems in the airplane. Even in older and less-sophisticated airplanes, many of the data measurements come from an interface with the digital flight data recorder (DFDR) system. Modern aircraft rely on aircraft digital data buses for data input, as will those of the future. In these aircraft, the airborne system will select data from several thousand parameters.

The study addresses all these aspects in detail, including management, hardware and software processes, program staffing requirements, crew member organizations, operations considerations, cost considerations and design drivers.

Design drivers are objectives and constraints that an airline should consider when designing a FOQA program. They lead to the fundamental decisions that must be made in formulating a design specification, in selecting hardware and software and in developing theprocesses.

The study also addresses system topics that apply at an inter-airline or national level.

The study also addresses system topics that apply at an inter-airline or national level. Major topics include overall aspects of information security, inter-airline data exchange, regulatory agency participation, FOQA implementation in the United States, post-study alternatives, FAA functional requirements, transition processes for national implementation, industry costs and other considerations.

FOQA Operation and Management Issues Outlined

The study report discusses FOQA management styles and reporting structure. Responsibilities for data processing, control and data cross-utilization to support multiple program objectives were gathered and analyzed. This process provided insight into the issue of confidentiality within specific organization elements responsible for FOQA data.

FOQA fleet sizes and monitored flight segments of FOQA airlines are also addressed in the study. Aircraft varied from older DC-9s to new B-747-400s. The number of aircraft monitored per operator ranged from 11 to 203.

Program staffing requirements are important in evaluating program implementation and operating costs. Costs of a program will vary widely depending on the size of the airline, the number of aircraft monitored, the extent of analysis (e.g., read every segment or sample different flights) and the extent to which personnel can be cross-utilized. Information on initial implementation costs and annual recurring operating costs is presented in the study report and should be helpful to airlines contemplating a voluntary FOQA program.

The study gives examples of operational event categories. This concept was examined and documented, including the selection process, events selected, parameters used and the operational parameter limits that were established to trigger an event. Most operators have at least two defined levels of exceedance severity, and at least one operator has chosen four. Action taken is based on the level of severity.

Airborne data systems are examined and discussed. Comparisons of features are presented and all aspects of data retrieval were documented, including identification of the retrieval medium, frequency of removal, location of removal and volume of data retrieved. The study team visited the data playback and processing facilities of six users and three equipment manufacturers. Operational event programs were examined to identify the common elements among the operators. Important program characteristics included evaluation of the monitored data, review of exceedance event reports, required corrective action and procedures for ensuring data confidentiality.

Aircraft integrated monitoring systems (AIMS) capabilities and DFDR system parameters that are standard on production aircraft were also examined.

It must be emphasized that although all recorded aircraft data are used to support the operational quality of the airline operation, there is a clear distinction between flight operational data and engineering or maintenance data. Flight data must be protected from unwarranted disclosure and this concept is universal among the user airline programs surveyed. It requires special data-use rules and management policies.

Typical FOQA Management Structure Reviewed

The study report discusses airline system applications and outlines the external interfaces and common FOQA functional elements. A typical FOQA management structure is discussed and data-use agreements are described in general. Airborne system configurations are discussed, as are retrieval systems and options. Because of the earlier availability of tape systems and data use sensitivity, all FOQA operators currently use tape "quick access" recorders. Ground playback system configurations, data collection and retrieval are examined in the study report.

Assessment of exceedances and event trends utilized by the FOQA user airlines is examined and discussed. Data trending and records retention options are presented.

Assessment of exceedances and event trends utilized by the FOQA user airlines is examined and discussed.

Relevant costs for a modern FOQA program are difficult to estimate because most existing programs do not use state-of-the-art technology and many component manufacturers treat cost information as proprietary. Nevertheless, the study develops some conclusions about system costs.

The report discusses U.S. airline operational considerations and concerns. Planning and implementation considerations are also examined and discussed.

The study's conclusions and recommendations were grouped in two areas; one pertaining specifically to airline systems, focusing on individual air carriers; the other pertaining specifically to the FAA and others in the U.S. air transport industry.

The following are the main points of the study's conclusions and recommendations:

- FOQA implementation in the United States must move forward.
- Further analysis of FOQA program elements identified by this study must be undertaken to realize fully the benefits of FOQA in the United States.
- FOQA has more potential for improving operational safety than is being attained by current-user airlines.
- FOQA will support both the internal audit and the advanced qualification program (AQP).
- ARINC Communications Addressing and Reporting System (ACARS) transmission of FOQA data is not practical because of costs and concerns about data security.
- Separation of FOQA data and FAA-mandated data is easily accomplished.
- FOQA data recorded on aircraft with digital data buses are not affected by current DFDR specifications.
- Airlines contemplating introduction of a FOQA system should use the study report as a source of background information.
- Equipment just entering the marketplace or nearing production will have more features than earlier hardware for FOQA systems.
- Newer aircraft with digital data buses and complex integrated monitoring systems are more easily adapted to FOQA than older aircraft.

- Including older aircraft in the FOQA fleet may not be practical because of the cost of installation and operation considered against remaining useful life.

- Installing the airborne system used by current FOQA operators requires retrofitting a quick access recorder (QAR). This can present a problem for fleets in excess of 200 aircraft because of the large volume of cassettes generated by the QAR.

- Flight operations policies, procedures and philosophies affect the selection of event categories and exceedance limits, which will vary among different airlines, even for identical aircraft types.

- Airlines implementing FOQA should retain in-house software support during initial development and as subsequent changes are required.

- The greatest impediments to FOQA use in the United States are associated with providing assurances that there is adequate protection from the use of FOQA data for other than safety and operational improvements.

- FAA policy on compliance and enforcement, and indications of support for revision of the U.S. Federal Aviation Regulations (FAR) should alleviate airline and flight crew concerns.

- Airlines, through adequate internal policies as mentioned earlier, can proceed with FOQA programs and alleviate data security problems.

Based on these study conclusions, the following recommendations were made:

- The FAA should encourage voluntary FOQA implementation by U.S. operators.

Carriers must recognize the importance of early involvement of pilot organizations in FOQA program development…

A trial program should be instituted to demonstrate benefits and promote widest FOQA use; obtain flight crew support; evaluate technology provided by manufacturers; evaluate emerging equipment and research and development at the module and system levels; evaluate event categories, limits and standardizations; develop cost-effective processes; and evaluate how airlines might formulate FOQA data for FAA that does not compromise data security.

- The FAA should vigorously address information protection issues.

- The FAA should begin a definition phase to outline additional needs and products of a FOQA program.

- U.S. airlines should implement FOQA programs as described in the study report.

- Airlines that implement FOQA programs should closely monitor actions taken by the FAA and other FOQA users as FOQA policies and systems become clearly defined in the United States and as protection against misuse of data is ensured.

- Operators should take full advantage of the rapidly developing technical capabilities becoming available for both airborne and ground systems.

- Carriers must recognize the importance of early involvement of pilot organizations in FOQA program development and those without pilot unions should devise appropriate plans to involve their pilots.

- A FOQA program should be implemented in phases, beginning with a new airplane purchased from the manufacturer and utilizing the full resources of the manufacturer, equipment and software suppliers in designing the system.

- The U.S. and international air transportation industry should develop common

FOQA standards and specifications to allow the exchange of standardized information and the development of data bases that will permit attention to be focused on subjects that require improvement, to provide information that indicates the level of safety and to support joint industry and government research programs.

- The FAA should re-examine periodically the FOQA objectives and methodology defined by industry and government and update them as required.

The FAA should re-examine periodically the FOQA objectives and methodology defined by industry and government and update them as required.

Study Report Includes Substantial Reference Material

In addition to the discussion of many aspects of FOQA as summarized, the study report's appendices provide substantial reference material helpful to those contemplating a FOQA program implementation. For example:

Appendix A provides a glossary of FOQA acronyms, abbreviations and definitions.

Appendix B presents the survey form used to elicit information from current FOQA user air carriers.

Appendix C comprises the FOQA literature search, with brief summaries of significant resources and a complete list of references.

Appendix D is a chart depicting event categories used in current FOQA programs.

Appendix E presents in chart form the parameters associated with typical operational event categories.

Appendix F summarizes operators' approach airspeed event limits versus altitude.

Appendix G displays parameters used in current FOQA programs.

Appendix H presents, in flow chart form, the process involved in FOQA event review and corrective action procedures.

Appendix I presents event categories for state-of-the-art FOQA programs by operational mode: taxi-out, takeoff, climb, cruise, descent/approach, landing and taxi-in.

Appendix J lists parameters for state-of-the-art programs.

Copies of the report may be obtained directly from the Flight Safety Foundation at a cost of US$50 each for FSF members; US$75 each for non-members. ♦

About the Author

John H. Enders is vice chairman of the Flight Safety Foundation Board of Governors, and 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.

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

FSF Industry Briefing and FOQA Equipment Demonstration Scheduled for May

The Flight Safety Foundation is planning a briefing on the FOQA study report and its conclusions and recommendations for members of the aviation community. In addition, equipment vendors will be on hand to demonstrate their capabilities and to discuss specific needs with those interested in FOQA implementation. The industry briefing/demonstration is scheduled for May 26-28 at the Hyatt Regency Reston Hotel, Reston, Virginia, U.S. For more information, contact J. Edward Peery or Robert Vandel, FSF. Telephone: (703) 522-8300.

Aviation Statistics

Statistics Show Passenger Survivability In U.S. Air Carrier Accidents

by
Shung Huang
Statistical Consultant

The frequency of U.S. air carrier accidents has declined substantially since the introduction of jet transport aircraft into airline service in 1957.

The frequencies of air carrier accidents and fatal accidents varied from year to year, and accidents from 1957 to 1967 fluctuated between 112 and 69, with an annual average of 85. Fatal accidents varied from eight to 18, with an average of 13 per year.

Figures 1 and 2 (pages 15 and 16) show U.S. airline total accident and fatal accident rates per 100,000 aircraft flight hours. The two figures show that during the 35-year period, total accident rates dropped from about three accidents per 100,000 aircraft hours to .23 accidents per 100,000 aircraft hours. Fatal accident rates dropped from .40 accidents to .030 accidents per 100,000 aircraft hours. Both the total accident and the fatal accident rates decreased by a factor of nearly 13. These statistics indicate that U.S. airlines are now 13 times safer than they were about 30 years ago.

The reduction of total accidents as well as fatal accident rates is very significant. However, it is also important to examine airline safety in terms of the number of passengers who survived in fatal accidents.

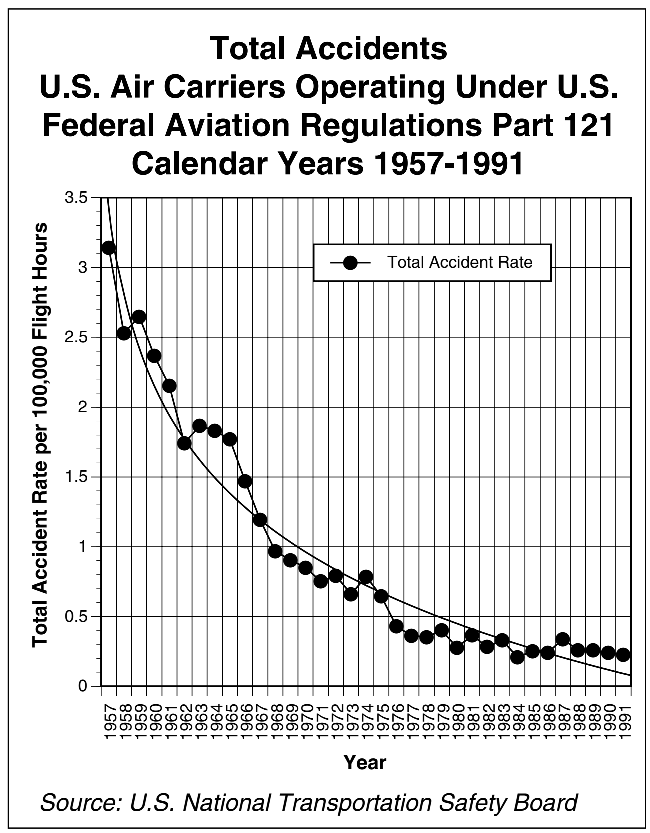


Figure 1

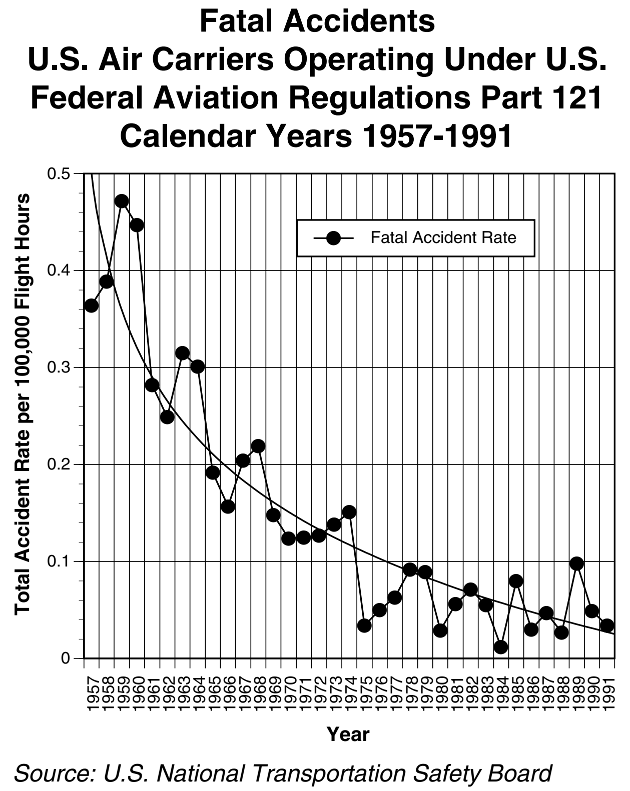


Figure 2

Study Reveals Survivability Ratios Prior to 1968

In a 1969 study of U.S. air carrier aircraft emergency evacuation systems failures, Flight Safety Foundation (FSF) reviewed U.S.-certified route and supplemental air carrier accident data from 1957 through 1967 and found that during the 11-year period, U.S. air carriers were involved in 931 accidents, 138 of which were fatal.

The study also revealed that of the 138 fatal accidents, 89 had no survivors, and 36 were survivable accidents involving passenger emergency evacuation. The remaining 13 fatal accidents involved fatal injuries to third parties on the ground with no passenger fatalities. There were 1,650 passengers and crew members aboard the aircraft involved in the 36 fatal accidents; 828, or 50.2 percent of the total persons aboard, were fatally injured. Only 822, or 49.2 percent, survived. Thus, in the period 1957 to 1967, the chance of passengers surviving in a survivable fatal accident was slightly less than 50 percent.

Passenger Survivability Has Improved

An analysis of U.S. National Transportation Safety Board (NTSB) air carrier accident data revealed that from 1968 to 1991, U.S. air carriers recorded a total of 803 accidents, 142 of which were fatal. Fatal accidents that fell into the following categories were excluded from the analysis.

- Fatal accidents without a survivor;
- Survivable fatal accidents occurring in non-passenger service, such as in cargo, ferry and training flights;
- Survivable fatal accidents due to violence, such as hijacking, sabotage and suicide;
- Ground accidents fatal to pedestrians on the runway, taxiway or any persons on the ramp when the aircraft involved was standing still; and
- Accidents involving fatal injury to passengers but not involving emergency evacuation or crash of the aircraft.

After review and classification, 101 fatal accidents were excluded and only 41 survivable accidents were suitable for this analysis. Of the 41 fatal accidents, 29 occurred during the 12-year period from 1968 to 1979. Twelve occurred between 1980 and 1991. A comparison of survivability rates for the three periods is shown in Table 1 (page 17).

The fatality ratio is defined to be the number of fatalities as a percent of total persons aboard the aircraft involved in the fatal accidents. The fatality ratio for the 1957-1967 period was 50.1 percent and increased slightly to 51.5 percent during the 1968-1979 period, but dropped to 41.8 percent in the 1980-1991 period. For the entire period, the overall decline was eight percent, which appears to be a positive indication that passengers' survivability in aircraft fatal accidents has been improving over the years.

Of the 36 survivable fatal accidents that occurred prior to 1968, only six involved jet transport aircraft. Table 2 shows the accident frequency and survivability rates of piston/turboprop aircraft and jet transport aircraft for the 1957-1967 period.

The survivability for passengers in piston/turboprop aircraft was 50.1 percent and 49.1 percent in jet transport aircraft, a difference of exactly one percent. This indicates that during the 1957-1967 period, the chances of airline passengers surviving in a piston/turboprop aircraft were one percent better than in a jet transport aircraft, although a one percent differentiation is too small to be considered significant.

Table 1
Comparison of Survivability Rates
Calendar Years 1957-1991

Description	1957-67*	1968-79	1980-91	Total
Survivable Fatal Accidents	36	29	12	77
Fatalities	828	1,322	639	2,789
Total Aboard	1,650	2,563	1,528	5,741
Fatality Ratio	50.1%	51.5%	41.8%	48.6%

* Flight Safety Foundation, *Study of Failure in Aircraft Emergency Evaluation Systems*, May 1969.

Source: U.S. National Transportation Safety Board

Since jet transport aircraft were introduced into U.S. airline passenger service in the late 1950s, they have become the major component of U.S. airline fleets. In recent years, jet transport aircraft have made up more than 90 percent of all U.S. large airline fleets, which carried more than 95 percent of the more tha 400 million passengers carried annually by U.S. air carriers. Therefore, the investigation of survivability of jet transport aircraft alone is more meaningful than investigation of all aircraft as a whole.

Tables 3 and 4 (pages 18 and 19) show the U.S. air carrier total accidents and fatal accidents involving piston/turboprop aircraft and jet transport aircraft for the period 1968-1991. Of the 142 fatal accidents, 88 of the aircraft were jet transports, 29 of which were survivable; and 54 fatal accidents involved piston/turboprop aircraft, 12 of which were survivable.

Tables 3 and 4 (pages 18 and 19) show the number of fatalities and total persons aboard the aircraft involved in the accidents. The survivability rate presented in the last column of the tables is the number of survivors of the fatal accidents as a percentage of the total aboard.

During the past 35 years, the survivability rate for jet transport aircraft improved from 49.1 percent to 61.4 percent. Thus, the passenger annual average survival rate is about 12 percent higher than it was 12 years ago.

The survivability rate for piston/turboprop, however, was down from 50.1 percent in 1957-1967 to 49.5 percent in the 1968-1979 period and dipped to 39.6 percent in 1980-1991. The negative trend in piston/turboprop aircraft accidents may not be conclusive because only two survivable fatal accidents were reported in the last 12 years. ♦

Table 2
Analysis of Survivable Fatal Accidents
By Aircraft Type
Calendar Years 1957-1967

Description	Piston/turboprop Engine Aircraft	Jet Transport Engine Aircraft	Total
Fatal Accidents	30	6	36
Fatalities	591	237	828
Total Aboard	1,184	466	1,650
Survival Rate	50.1%	49.1%	49.2%

Source: U.S. National Transportation Safety Board

Table 3
Accidents, Fatal Accidents and Fatalities Involving Jet Transport Aircraft Of U.S. Air Carriers Operating Under U.S. Federal Aviation Regulations Part 121 All Passenger Service Calendar Years 1968-1991

Year	Total Accidents	Fatal Accidents	Fatal Jet Accidents	Survivable Jet Accidents @	Fatalities*	Total Aboard	Survival Rate
1968	62	14	3	1	6	63	90.45%
1969	61	10	4	0	0	0	—
1970	55	8	6	2	49	282	82.7%
1971	48	8	7	0	0	0	—
1972	50	8	5	3	152	282	53.9%
1973	43	9	7	2	166	168	1.0%
1974	47	9	7	2	167	183	8.7%
1975	38	2	1	1	112	124	8.2%
1976	26	3	2	2	38	138	72.5%
1977	23	4	3	2	389	481	19.2%
1978	23	6	4	3	15	444	97.1%
1979	27	6	2	1	70	87	19.5%
Subtotal	503	87	52	19	1,164	2,252	48.3%
1980	19	2	0	0	0	0	—
1981	26	4	0	0	0	0	—
1982	20	5	5	1	74	79	6.3%
1983	24	4	1	0	0	0	—
1984	17	1	0	0	0	0	—
1985	22	7	4	1	134	163	17.8%
1986	24	3	0	0	0	0	—
1987	36	5	5	2	182	237	23.2%
1988	29	3	3	1	14	108	87.0%
1989	29	11	10	3	122	714	82.1%
1990	29	6	5	1	8	42	80.9%
1991	27	4	3	1	22	99	77.7%
Subtotal	300	55	36	10	556	1,442	61.4%
Total	803	142	88	29	1,720	3,694	53.4%

@ The fatal accidents wherein at least one passenger survived.
* Fatalities in survivable fatal accidents.

Source: U.S. National Transportation Safety Board Annual Review of U.S. Air Carrier Accidents 1968-1991.

Table 4
Accidents, Fatal Accidents and Fatalities Involving Piston/Turboprop Aircraft of U.S. Air Carriers Operating Under U.S. Federal Aviation Regulations Part 121
All Passenger Service
Calendar Years 1968-1991

			Piston/turboprop Aircraft				
Year	Total Accidents	Total Fatal Accidents	Fatal Accidents	Survivable Accidents @	Total* Deaths	Total Aboard	Survival Rate
1968	62	14	11	4	114	171	33.3%
1969	61	10	6	3	15	45	66.7%
1970	55	8	2	0	0	0	—
1971	48	8	1	0	0	0	—
1972	50	8	3	1	17	40	57.5%
1973	43	9	2	0	0	0	—
1974	47	9	2	0	0	0	—
1975	38	2	1	1	10	32	68.7%
1976	26	3	1	0	0	0	—
1977	23	4	1	0	0	0	—
1978	23	6	1	0	0	0	—
1979	27	6	4	1	2	25	92.0%
Subtotal	503	87	35	10	158	313	49.5%
1980	19	2	2	1	13	15	13.3%
1981	26	4	4	0	0	0	—
1982	20	5	0	0	0	0	—
1983	24	4	3	0	0	0	—
1984	17	1	1	0	0	0	—
1985	22	7	3	1	70	71	1.3%
1986	24	3	3	0	0	0	—
1987	36	5	0	0	0	0	—
1988	29	3	0	0	0	0	—
1989	29	11	1	0	0	0	—
1990	29	6	1	0	0	0	—
1991	27	4	1	0	0	0	—
Subtotal	300	55	19	2	83	86	4.5%
Total	803	142	54	12	241	399	39.6%

@ The fatal accidents wherein at least one passenger survived.
* Fatalities in survivable fatal accidents.

Source: U.S. National Transportation Safety Board Annual Review of U.S. Air Carrier Accidents 1968-1991.

Publications Received at FSF Jerry Lederer Aviation Safety Library

by
Editorial Staff

Reports

Altitude Deviation Study: A Descriptive Analysis of Pilot and Controller Incidents/Washington, D.C. U.S. Federal Aviation Administration (FAA), Research and Development Service, 1992. x, 436 p.

Keywords

1. Air Traffic Control — Automation.
2. Air Traffic Control — Communication.
3. Air Pilots — Performance.

Summary: This report provides results of a FAA funded human factors study to identify causal factors of altitude deviations. The study was conducted in conjunction with a USAir/U.S. Air Line Pilots Association (ALPA) altitude awareness program.

The report contains an extensive literature search to provide information pertaining directly to altitude deviations from the human factors psychology and engineering community. A bibliography of references compiled for this literature search is also included.

Although human factors information associated with altitude deviations was relatively scarce, incident reports from the U.S. National Aeronautics and Space Administration's (NASA) Aviation Safety Reporting System (ASRS) database pointed to a large number of human factors that contributed to the occurrence of altitude deviations, including aural and visual displays; automation and system designs; cognitive processes; crew interaction and team behavior; human error in incidents and accidents; information transfer and communications; performance effects (stress and fatigue); and pilot workload. Pilot/controller incident and survey data were collected and analyzed using human factors methodologies to provide pertinent conclusions and recommendations. Incident reports provided information from actual deviation occurrences, while surveys provided subjective information from the participating pilots and controllers. Analysis revealed pilot and/or controller communication problems, procedural issues and training issues were the three prominent causes of altitude deviation.

The study concludes with the altitude deviation study workshop notes. This workshop was held to inform national airspace users and operators of the methodology and workings of the study, and to review its key elements with government and industry representatives. According to the report, a vital outcome of this study was the successful implementation of a "team approach."

Passenger Electronic Devices Reports/U.S. National Aeronautics and Space Administration (NASA), Aviation Safety Reporting System (ASRS). Mountain View, California. Available through NASA, Ames Research Center, 1993. 56 p.

Keywords

1. Airplanes — Electrical Equipment.
2. Aeronautics, Commercial — Passengers.
3. Air Traffic Control — Communication Systems.

Summary: This material was gathered from ASRS reports on instances of passenger electronic devices (PED) affecting aircraft communications or navigational equipment. This sample provides 40 incidence reports of suspected interference to communications or navigational equipment from PEDs ranging from cellular phones to laptop computers. These reports came from a database containing 43,394 full-form records received since Jan. 1, 1986. Each report provides a narrative of the incident and a synopses of the suspected causal factors.

Aircraft Accident Report: United Airlines Flight 585 Boeing 737, N999UA, Uncontrolled Collision with Terrain for Undetermined Reasons 4 Miles South of Colorado Springs Municipal Airport, Colorado Springs, Colorado, March 3, 1991./U.S. National Transportation Safety Board (NTSB), Washington, D.C., 1992. vii, 160 p. Available through National Technical Information Service*.

Keywords

1. Aeronautics — Colorado — Accidents.
2. Aeronautics — Accidents.
3. Boeing 737 (Jet Transport) — Accidents.

Summary: Shortly after completing its turn onto the final approach course to Colorado Springs Municipal Airport, the Boeing 737 airplane rolled suddenly to the right and pitched nose down until it reached a nearly vertical attitude before hitting the ground.

The airplane was destroyed, and the two flight crew members, three flight attendants and 20 passengers were fatally injured.

At the time of departure from Denver, the reported weather conditions around Colorado Springs were clear, visibility 100 miles, and winds at 23 knots with gusts to 33 knots. En route the flight crew received automated terminal information service (ATIS) information that low level wind shear advisories were in effect. A local aviation wind warning was in effect calling for winds out of the northwest, gusts to 40 knots and above.

According to the flight data recorder (FDR) and cockpit voice recorder (CVR), the flight crew added 20 knots to the approach airspeed based on ATIS information. While on approach, at 11,000 feet, Flight 585 was vectored to runway 35 for a visual approach. Wind information was issued as 320 degrees at 13 knots, gusting to 23 knots.

About five minutes later, while descending, the first officer reported to the tower, “cleared for a visual to 35.” When the local controller cleared the flight to land the wind report was issued as 320 degrees at 16 knots with gusts to 29 knots. When the first officer inquired about reports of loss or gain of airspeed from other airplanes, the local controller replied that a Boeing 737 reported a “15-knot loss” at 500 feet, “plus 15 knots” at 400 feet , and “plus 20 knots” at 150 feet. This was the last weather information exchanged between approach control and Flight 585 before the accident.

More than 60 witnesses were interviewed during the initial investigation. The majority of those who observed the aircraft indicated that although the plane was flying lower than what they were accustomed to seeing, it appeared to be operating normally until it suddenly rolled to the right and descended into the ground. The NTSB, after an exhaustive investigation effort, could not identify conclusive evidence to explain the loss of United Airlines Flight 585. According to the report, the two most likely events that could have resulted in a sudden uncontrollable lateral upset are a malfunction of the airplane’s lateral or directional control system, or an unusually severe atmospheric disturbance, possibly a rotor (a horizontal axis vortex), produced by high winds aloft and the mountainous terrain. As a result of the investigation, the NTSB made several recommendations to the U.S. Federal Aviation Administration regarding the 737 rudder system; and made a further recommendation to develop a program to observe, document and analyze potential meteorological aircraft hazards in the Colorado Springs area.

Books

Hypokinesia and Weightlessness: Clinical and Physiologic Aspects/Oleg Y. Atkov and Victor S. Bednenko; translated from the Russian by George Watts. Madison, Connecticut: International Universities Press, 1992. xix, 560 p.

Keywords

1. Weightlessness — Physiological Aspects.
2. Hypokinesia — Physiological Aspects.
3. Immobilization — Physiology.
4. Space Flight.
5. Weightlessness.

Summary: This technical study deals with medical aspects of the former Soviet Union's manned space program and reviews findings from U.S. and Soviet space missions. The collective U.S./Soviet space-travel experience has shown that despite careful selection and use of preventive measures, the health of up to 75 percent of crew members was affected by weightlessness.

In light of further planned space missions, including a possible two-year mission to Mars, this study provides important data on the prolonged effect of weightlessness on space crews. It summarizes and draws conclusions from the results of more than 10 years of the authors' research, as well as from numerous other works in space biology and medicine in the former Soviet Union and the United States. The research addresses the effect of weightlessness and hypokinesia (simulated weightlessness) on the cardiovascular system, internal organs and adaptability of the human body to zero or low gravity environments. The contents include sections on the adaption of the human organism's systems in hypokinesia and weightlessness; on methods of investigating the effects of weightlessness; on the system of the human organism in-flight and during the readaptation period; and on the results and future prospects of evaluating the human organism in hypokinesia and weightlessness. References, illustrations, subject and name indexes are also included. ♦

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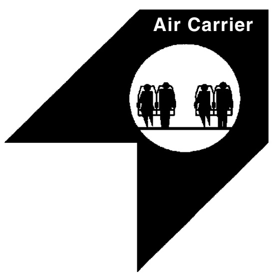
Accident/Incident Briefs

by
Editorial Staff

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 on preliminary information from government agencies, aviation organizations, press information and other sources. This information may not be entirely accurate.



Tragedy Narrowly Escaped After Runway Incursion

Airbus A320. Mooney 20K. Substantial damage. No injuries.

The A320 was on short final when a Mooney entered the runway for takeoff without clearance. The Airbus crew and air traffic control did not see the Mooney because of heavy fog.

On touchdown, the Airbus' nose gear struck the Mooney's right wing and the left wing was partially ingested by the A320's left engine. The Airbus slid straight down the runway with the broken nose gear and came to a stop about 750 meters after the collision. There was no fire and no injuries were reported.

Localizer Deviation Leads to Crash

Boeing 707-300. Aircraft destroyed. Seven fatalities.

The international cargo flight was on a daylight instrument landing system (ILS) approach to a European airport.

The aircraft deviated from the ILS localizer about three nautical miles from the airport. Seconds later, the aircraft struck a 2,000-foot hill. It was destroyed by the impact and fire.

Control Loss Follows Severe Turbulence

DHC-6. Twin Otter. Aircraft destroyed. Five fatalities.

During the initial climb, the commuter encountered strong wind shear and severe turbulence. Control of the aircraft was subsequently lost and it crashed into the sea.

A post-crash investigation found a fatigue failure of the push/pull rod to the elevator. Loss of the flight control system was attributed to turbulence damage and the resulting fatigue failure. Three passengers and two crew members were killed in the daylight accident.

Trees Terminate Short Final

Fairchild FH227. Aircraft destroyed. Twenty-three fatalities. Nineteen serious injuries.

The Fairchild was on a night visual flight rules (VFR) approach to a South American airport. On short final, the aircraft was allowed to descend too quickly and it collided with trees and crashed about one kilometer from the runway threshold.

Corporate Executive

Cliff Ends Search for Ground Cues

Piper PA-31. Aircraft destroyed. Three fatalities.

The aircraft was approaching a Swedish airport at night with low clouds covering the approach track.

The aircraft collided with a vertical cliff at the 728-foot mark on an 821-foot mountain slope about six nautical miles from the runway threshold.

The collision occurred in level flight with normal engine power. An investigation determined that the pilot descended from a safe altitude to search for ground cues after the weather deteriorated rapidly and that he apparently headed for an illuminated factory located near the airport.

Other General Aviation

Fatal Dive Linked to Poor Stall Recovery

Fournier RF5. Aircraft destroyed. One fatality. One serious injury.

After takeoff, the aircraft appeared to climb steeply. It entered a left turn and vibration occurred.

The pilot lowered the nose and slightly reduced the angle of bank. The vibration stopped and the aircraft's speed increased to about 80 mph, although it had lost about 200 feet of altitude. The pilot raised the nose again and the vibration returned. This time the aircraft did not recover and descended in a steep left turn until it struck the ground.

The pilot was killed and the passenger seriously injured. An inquiry determined that the pilot stalled the aircraft unintentionally in the turn and mishandled the recovery, putting the aircraft into a secondary stall from which he was unable to recover. The pilot had logged a total of 285 hours with nine hours in type.

Student Pilot Ignores Weather Avoidance Plan, Meets Mountain Ridge

Cessna 150. Aircraft destroyed. One serious injury.

The student pilot was on a cross-country flight when the weather began to deteriorate and cloud cover increased.

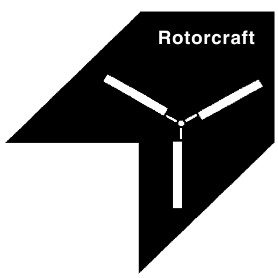
While waiting for a radio weather update, the pilot flew the aircraft into a cloud and crashed near the top of a mountain peak. The aircraft was destroyed. An investigation determined that the student pilot had failed to follow briefing instructions regarding possible adverse weather. The pilot had logged a total of 150 hours flying time.

Tailwind Landing Sinks Beaver

DHC-2 Beaver. Substantial damage. Minor injuries.

The float-equipped single-engine Beaver landed with a 25-knot tailwind and touched down long on the water. Fearing the aircraft would not stop before reaching the shore, the pilot pushed the nose down to slow the airplane.

The floats dug in and the aircraft overturned, tearing off the floats and wings. The pilot escaped the wreckage with minor injuries



One Hand Too Many Puts Hughes on the Skids

Hughes 269A. Substantial damage. No injuries.

While at low hover, the passenger in the Hughes leaned forward and inadvertently pushed the cyclic stick forward. Before the pilot could recover from the nose-low attitude, the skids struck the ground.

When the pilot abruptly moved the cyclic to the rear, it caused the main rotor blades to cut off the tailboom. There was no fire and the pilot and passenger escaped without injury.

Fuel Required for Aerial Application Missions

Bell 47G2. Substantial damage. Minor injuries.

The helicopter had been spraying a peanut field. While en route to refuel, it suddenly lost power.

The engine stopped when the aircraft was about 200 feet above the ground. The pilot maneuvered the helicopter toward a corn field and attempted an autorotation. The aircraft was substantially damaged in the subsequent hard landing. An inspection of the helicopter's fuel system revealed that one pint of fuel remained in the aircraft.

Landing Area Obstruction Drives Pilot to Distraction

Bell 206A. Substantial damage. Five minor injuries.

The helicopter was returning from a 15-minute sightseeing flight. The pilot initiated a descending turn to land and became distracted by his client's vehicle parked in the landing area.

The Bell struck trees and crashed. The pilot and four passengers received minor injuries.♦