FLIGHT SAFETY FOUNDATION

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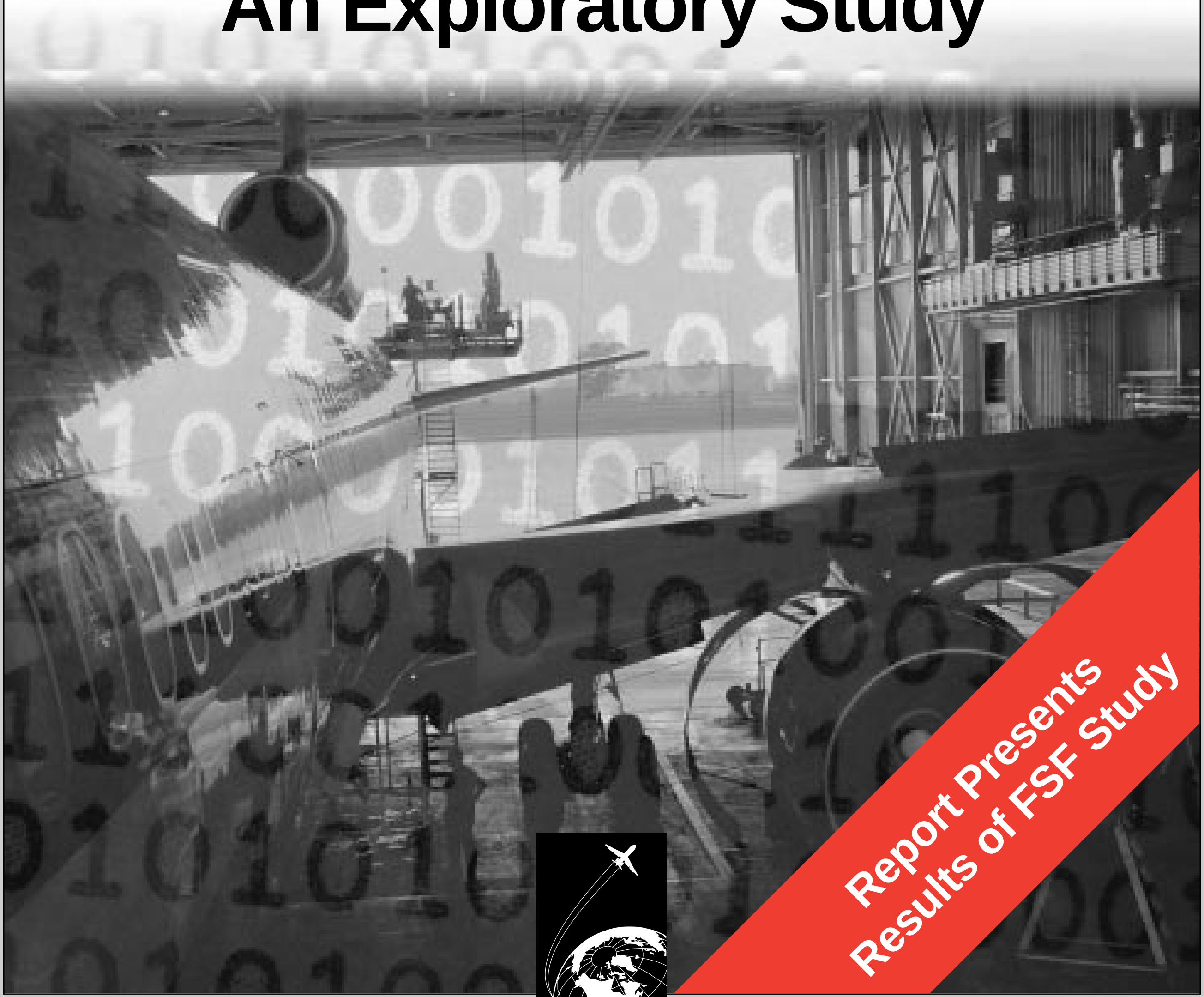
# FLIGHT SAFETY DIGEST

SPECIAL DOUBLE ISSUE

# Continuing Airworthiness Risk Evaluation (CARE): An Exploratory Study



Report Presents Results of FSF Study

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## In This Issue

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*Flight Safety Foundation is an international membership organization dedicated to the continuous improvement of flight safety. Nonprofit and independent, the Foundation was launched in 1947 in response to the aviation industry's need for a neutral clearinghouse to disseminate objective safety information, and for a credible and knowledgeable body that would identify threats to safety, analyze the problems and recommend practical solutions to them. Since its beginning, the Foundation has acted in the public interest to produce positive influence on aviation safety. Today, the Foundation provides leadership to more than 850 member organizations in 100 countries.*

# Continuing Airworthiness Risk Evaluation (CARE): An Exploratory Study

*Methods for evaluation and management of continuing airworthiness are evolving. Advances depend on accurate, dependable databases compiled by government and private organizations. Such databases include events that, when aggregated, provide a data-driven means for evaluating the airworthiness of airplane models, operator fleets, individual airplanes or airplane systems. Combining various databases promises even more precise airworthiness monitoring, but considerable progress in standardization must occur before that promise can be realized.*

*John H. Enders*
*Robert S. Dodd*
*Frank Fickeisen*

## 1 Executive Summary

This report presents the results of the Flight Safety Foundation (FSF) Continuing Airworthiness Risk Evaluation (CARE) study. The primary question in this study was: "Can current information sources be used better to identify and quantify factors influencing continuing airworthiness?" The hypothesis was that various current data sources, if used in combination, could be more effective in identifying and quantifying hazards, and in guiding actions to overcome airworthiness-related risks before accidents/incidents can occur.

The study, providing a snapshot of a small part of the aviation industry, found that:

- Within the U.S. government, the industry and safety organizations, there are many databases and database-analysis systems relevant to aviation-safety issues (e.g., accidents/incidents, human error, hardware reliability and software adequacy);
- Private data could provide useful augmentation of public databases for proactive safety purposes, but methods of using private data without compromising proprietary information and competitive business issues must be developed;
- Private data, as well as public data, are in a variety of software formats and software applications that make the most efficient use of them difficult. Formats that are suitable for a limited use of the data are likely to be unsuitable for correlation or combining of the data elements. Since the early 1990s, the U.S. Federal Aviation Administration (FAA) Office of System Safety has been able to perform some data translation, aggregation and analysis through the National Aviation Safety Data Analysis Center (NASDAC);
- Perceptions about misuse of private data create a reluctance to share safety data, and this will impede expanded use of private data for an integrated and unified method of aviation-safety improvement;
- Selective data sharing within the industry is providing some benefits, but far fewer than would be derived from a wider sharing of information from individual flight operational quality assurance (FOQA) programs; more often, results — not raw data — are shared. Efforts are

under way to go beyond the organizational level to share information with a wider audience; and,

- Inadequate feedback of government analysis of data to the suppliers of the data — the operators and manufacturers — results in a reluctance to report events. Producers of information who believe that required reporting does not provide a reasonable return of benefits (a "one-way system") are not likely to participate with enthusiasm. Often data have been collected; the issues are how to make more effective use of data, how to select data better and how to reduce the volume of data.

## 2 Background

FAA questioned the effectiveness of specific continuing-airworthiness practices by government and industry, and in particular, whether the content of privately held airworthiness data differs significantly from that of public data, and whether the private data offer the potential for safety improvements.

In the autumn of 1996, the FSF CARE study team began a study to learn if better use of current sources of data could improve the safety outcomes and efficiency of the continuing-airworthiness process for the air transport industry.

### 2.1 Definitions

*Airworthiness* can be defined as the condition of an item (airplane, system or part) in which that item operates in a safe manner to accomplish its intended function. *Continuing airworthiness* can be defined as maintenance through the full service life of an item (airplane, system or part) to ensure that the item operates in a safe manner to accomplish its intended function. *Maintenance* can be defined as the process of inspecting, repairing or replacing parts and/or components to ensure that the airplane meets the airworthiness standards to which the airplane was certificated.

Usually, continuing-airworthiness processes maintain or restore an airplane, airplane system or part to the standards established by the original airworthiness processes (design, manufacture, certification, etc.). Nevertheless, service experience sometimes indicates that the original standards were not comprehensive or rigorous enough from a safety perspective. Service experience occasionally may indicate that extensions or reductions of service life expectations should be considered. For these unusual (but important) situations, the continuing-airworthiness process will lead to adjusted specific design standards or service life values, and perhaps to new or revised regulations or advisory material.

### 2.2 Airworthiness-related Accidents/Incidents

Airworthiness-related accidents often have their origin in an erroneous human decision by the flight crew or by maintenance personnel. An airworthiness-related anomaly presents the flight crew with a situation requiring a decision to resolve or mitigate the risk. Although the airworthiness anomaly might originate in processes remote in time and place from the actual flight (such as design, manufacture, maintenance or inspection), generally the flight crew must respond to the situation.

Company policies also may lack specificity that would, in some cases, provide sufficient guidance to flight crews and maintenance crews, and enable them to avoid the need for decisions that could lead to a chain of events with increasing risk. Depending on the nature of the anomaly, the chain of events could be trivial or serious.

The timeliness of crew intervention is also a factor in dealing successfully with the anomaly. Airworthiness anomalies may be resolvable, but human decision errors made under the pressures of in-flight decision making can compound the risk. Serious airworthiness-related incidents — events that present high risk but are resolved before they develop into an accident — are important because the potential consequences are significant. Consider the following examples:

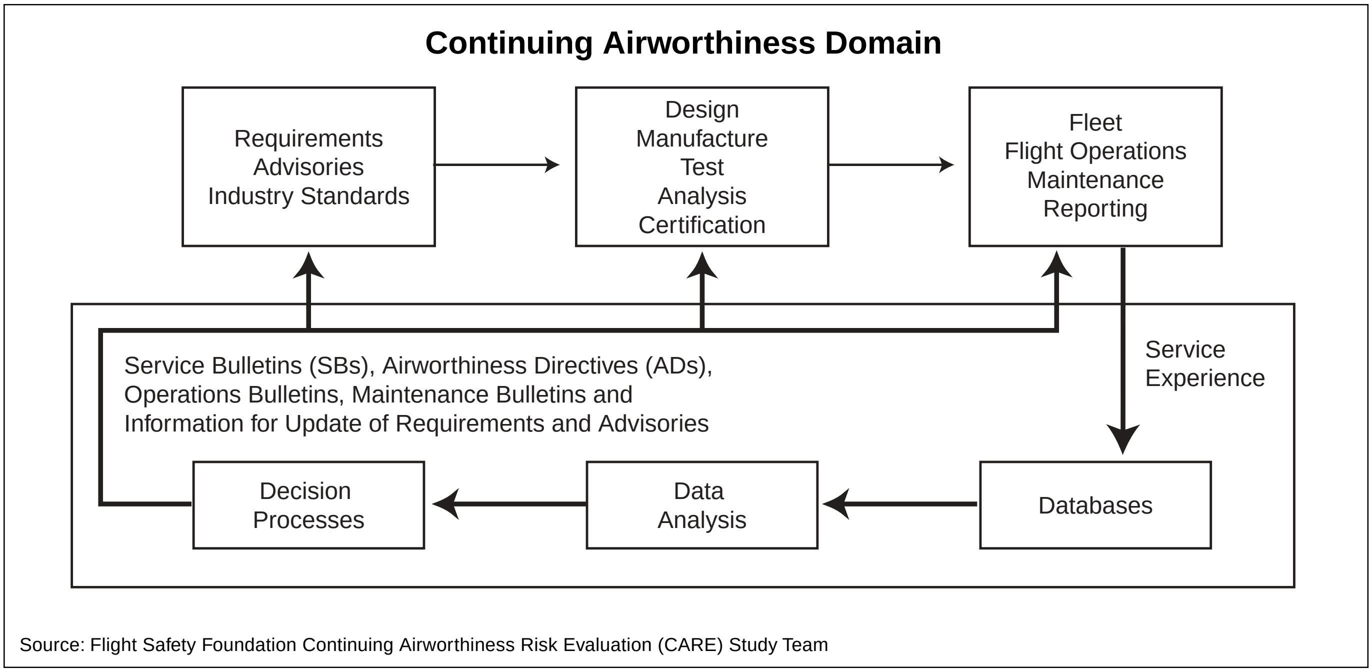
- An accident was caused by the uncommanded in-flight deployment of a thrust reverser. The deployment was the result of electrical and/or mechanical anomalies and failure modes that allowed hydraulic pressure to a directional-control valve to be applied incorrectly to the reverser-extend port. This accident led to a number of design and installation changes in the reverser system;

- Extreme precipitation resulted in flameouts of both engines and the airplane's subsequent off-airport landing. The airplane received minor damage and later was flown from the landing site. Response to this incident resulted in the following: (a) flight operations instructions were reviewed and changed to emphasize the importance of avoiding hazard exposure (minimizing flight into very heavy precipitation); (b) design changes were made to the engine to minimize the likelihood of flameout in heavy precipitation; and (c) engine-design standards for rain and hail ingestion were subsequently reviewed and adopted; and,

- One operator's fleet experienced a small number of main electric-generator failures. Investigation led to the conclusion that the oil being used to service the integrated drive generator (IDG) by this operator might have been the source of generator-brush failures. The oil was approved for IDG servicing. Nevertheless, a different and more commonly used oil was substituted, and the problem did not recur.

### 2.3 Underlying Concepts in Continuing Airworthiness

Figure 1 shows a continuing-airworthiness process, which has three distinct, serial steps: (a) databases, accumulation of


Continuing Airworthiness Domain

Source: Flight Safety Foundation Continuing Airworthiness Risk Evaluation (CARE) Study Team

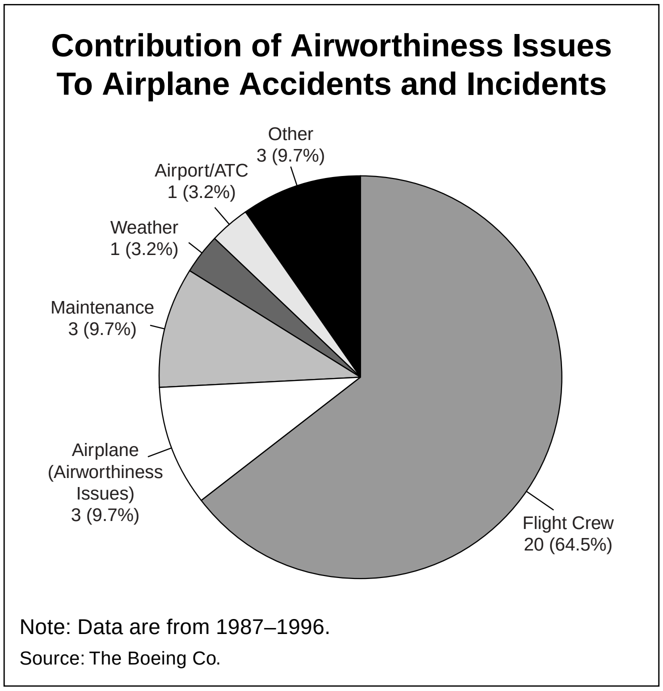
**Figure 1**

data based on service experience; (b) data analysis, analysis of the accumulated data, which may include comparison to the original certification processes and results; and (c) decision processes, decision making (by accident-investigation authorities, by certification authorities and by manufacturers and operators). Each step may present difficulties, including the acquisition of sufficient human resources and computer resources for database construction and database analysis.

### 2.3.1 Proactive Safety Concept

Aviation safety has, since the beginning of human flight, depended on investigation of accidents/incidents to determine their causes. By this means, designs of airframe structures, powerplants, systems and accessories have been improved to reduce opportunities for failure. With few exceptions, this has been an incremental method, with the introduction of totally new technologies providing periodic “quantum leaps” of progress. Likewise, the lessons learned from accidents/incidents have provided the basis for developing training processes, standardizing operational procedures and developing checklists, while providing information for pilots and maintenance personnel to hone their skills and decision-making abilities.

As demand for civil air transportation of passengers and cargo has continued to increase, the accompanying increases in numbers of aircraft and numbers of flights have added exposure to risk of increased numbers of accidents. Figure 2 shows the relative proportions of accidents and incidents that have been attributed to airworthiness issues. The few accidents that occur can be broadly categorized, but the causal pattern is elusive because of their rarity and reveals no significant pattern for airplane design-related items. Outcomes — including controlled flight into terrain, approach-and-landing accidents and airplane upsets — can be grouped, but the causes associated with the outcomes often vary, exceeding the ability to categorize them. Figure 3 (page 4) shows the relationship among three contributory requirements in airplane accidents and incidents, for example. Retrospective analysis has reached a limit in providing means of further reducing the airworthiness-related accident rate.

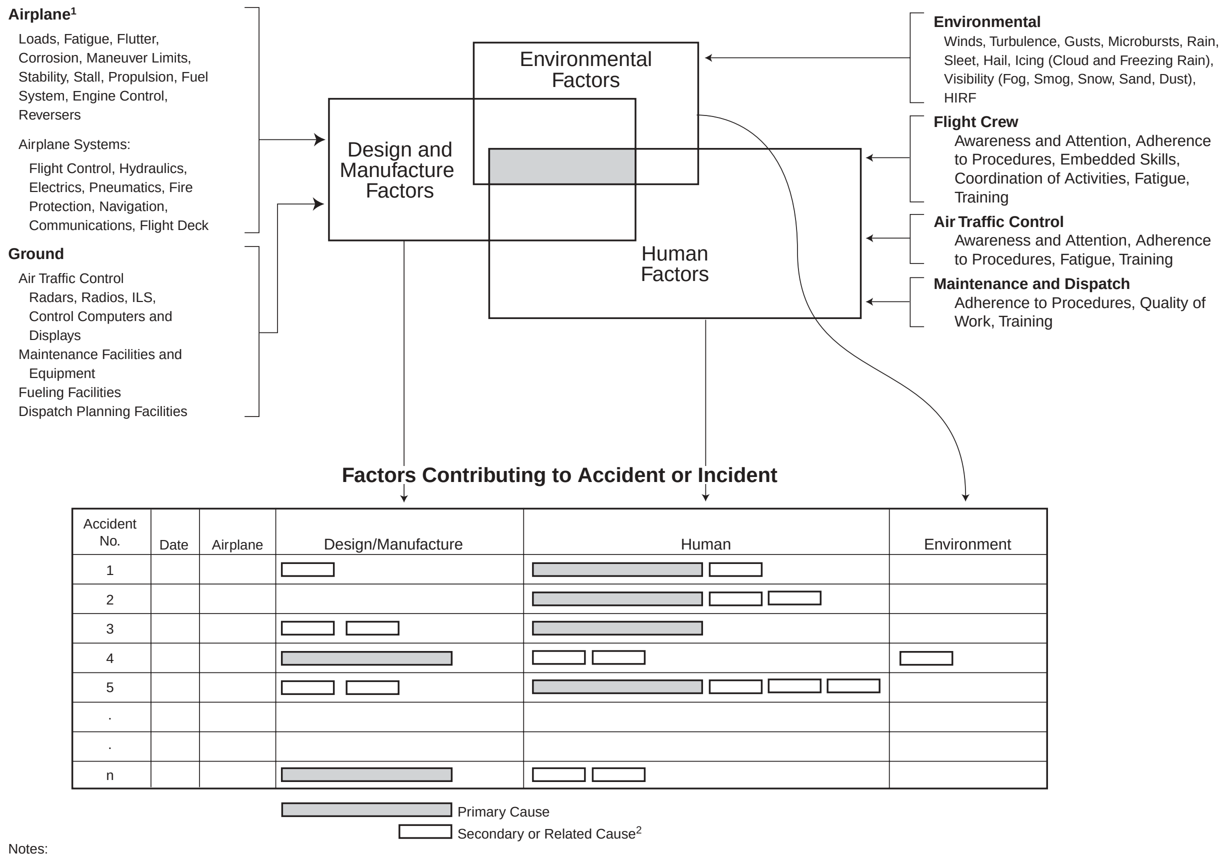

Contribution of Airworthiness Issues To Airplane Accidents and Incidents

Note: Data are from 1987–1996.

Source: The Boeing Co.

**Figure 2**

**Relationship of Contributory Requirements in Accidents and Incidents**



| Accident No. | Date | Airplane | Design/Manufacture | Human | Environment |
|---|---|---|---|---|---|
| 1 | | | ☐ | ▨ ☐ | |
| 2 | | | | ▨ ☐ ☐ | |
| 3 | | | ☐ ☐ | ▨ | |
| 4 | | | ▨ | ☐ ☐ | ☐ |
| 5 | | | ☐ ☐ | ▨ ☐ ☐ ☐ | |
| . | | | | | |
| . | | | | | |
| n | | | ▨ | ☐ ☐ | |

▨ Primary Cause

☐ Secondary or Related Cause[2]

Notes:

1. The lists of airplane, ground, environmental, flight crew, air traffic control, maintenance and dispatch factors are incomplete.
2. The number of secondary or related causes associated with any accident/incident will vary greatly (in the range of zero to twenty or more).

ILS = Instrument landing system HIRF = High-intensity radiated fields

Source: Flight Safety Foundation Continuing Airworthiness Risk Evaluation (CARE) Study Team

**Figure 3**

Most airworthiness-related accidents are preceded by precursor events that might not be recognized before the accident. Consequently, in recent years, both the public and private sectors have been searching for a means to aggressively identify latent conditions that become enabling factors that lead to an accident/incident.

Latent conditions can originate from:

- Incomplete or incorrect equipment designs;
- Procedures or checklists that do not account for human errors;
- Incomplete training programs for ground and flight personnel;
- Improper or incorrect repairs or maintenance;
- Manufacturing processes with undetected material or assembly flaws; and,
- Management decisions that enable incompatible organizational processes or inadequate funding to support essential functions.

By recognizing the latent conditions that lead to failures, intervention can be made to prevent accidents. This is at the core of the many proactive methods (contrasted with reactive accident-investigation feedback) being applied in the industry today (see Reason[1]).

### 2.3.2 Risk Evaluation

Continuing airworthiness encompasses many different methods of analysis, including risk evaluation. Risk evaluation develops strategies to improve safety and to reduce accidents/incidents in a variety of industries. The basic concept of risk evaluation is to measure risk (often defined in probability terms) of occurrence of an accident/incident. Three main factors must be considered when conducting risk evaluation: identification of the event or scenario of interest; determination of the likelihood that factors in the event or scenario will occur; and determination of the consequence of that event or scenario (its seriousness) if it occurs. In such analyses, the estimate of risk usually is based on the past performance of the system.

Effective risk-evaluation processes for aviation safety, however, are difficult to create. These processes are data-driven; that is, they rely on the collection and analysis of in-service data for each aircraft. The types of data that need to be collected include:

- In-service exposure of the aircraft (flight hours and takeoff-and-landing cycles);
- In-service exposure of the failed part or component (part total time [TT] and cycles, and part time since overhaul [TSO] and cycles);
- The specific in-service environment for the failed part or component (date, flight phase in which failure occurred, temperatures, acceleration and vibration conditions, etc.);
- Aircraft make, type, serial number, registration number and other descriptive data;
- Part name, manufacturer and serial number;
- Failed component category, usually based on an Air Transport Association of America (ATA) Specification 100 code[2] from *SPEC 100: Manufacturers Technical Data* — commonly called an ATA chapter — or a related derivative; and,
- Event hazard evaluation (which usually requires a specialist's opinion with reference to historical outcomes).

In summary, continuing airworthiness risk evaluation must include the following elements:

- Collecting high-quality data;
- Calculating material-related failures and incident trends;
- Identifying components or systems that exceed a known baseline of acceptable performance;
- Investigating causes of baseline exceedance;
- Intervening with corrective action; and,
- Monitoring the effectiveness of the intervention.

### 2.3.3 Data Quality

CARE programs depend on adequate data sources. For example, if the exposure data concerning the number of hours or cycles for a part or airplane are in error, or the total number of incidents is under-reported, risk estimates will be in error. Data input will be derived from a variety of sources, including digitally recorded maintenance data on newer airplanes and data that are manually collected, categorized and entered into databases through operators' maintenance programs on older airplanes. Significant data often are retrieved from the field representatives of airframe manufacturers if not otherwise reported by the operator; sometimes a local newspaper article prompts the field representative's research.

Characteristics of high-quality data include accuracy, reliability and validity.

- Accuracy of data refers to the precision of reporting and recording. A report could be reliable (landing gear-switch failure is correct), valid (the landing gear-switch failure is caused by material failure) but not accurate because the part number, date, resolution and other associated data were not recorded correctly;
- Reliability means that the same event is always identified and recorded the same way. If, for example, an individual in California, U.S., reports a particular type of landing gear–switch failure, and another individual experiences the same failure in Georgia, U.S., then both of these events should be recorded the same way in the database; and,
- Validity means that the data identified in the database are the data that the database designer wanted to be recorded. If the landing-gear switch is just dirty, but data are recorded as the switch having failed because of material failure, these data are not valid. Both situations involve a failed switch, but the underlying cause was recorded incorrectly in one situation. This would create problems in using the database to determine why so many landing gear-switch problems were occurring.

The quality of the associated narrative also is important, because consistent coding is required to ensure that the data are reported uniformly and that the same types of events are recorded the same way.

Evaluating hazard levels (comparing serious hazards with less serious hazards for a given time) for each event and ensuring that the data are uniform and reliable are labor intensive. The process requires individuals who are knowledgeable in aviation maintenance and airworthiness, and skilled in database structure and data entry. This represents a significant investment for most organizations. As a result, only organizations that have the infrastructure to support such a process can incorporate a fully functioning CARE program into their operations.

The lack of a CARE program does not indicate that an organization is not operating safely. Many organizations rely on the expertise of their maintenance departments, which receive support from the manufacturers and from the appropriate airworthiness authority. Nevertheless, recognizing trends that permit confident decision making requires sufficient data sets — a sufficiently large fleet — especially to support a proactive program that requires early recognition of enabling factors or events on a "diagnostic curve."

### 2.3.4 Leveraging of Experience Across the Fleet

Among operators of smaller fleets, there is an advantage to combining data for similar types of airplanes across several operators' fleets to provide the breadth of exposure and experience that can make analysis meaningful. To achieve this advantage, data must be shared among operators and associated manufacturers so that all parties can exploit knowledge of the data trends.

### 2.3.5 Data-analysis Processes

If commercial-aviation accident/incident factors were always the same, and could be counted on to remain so, then the need for forward-looking continuing-airworthiness processes would be low. In that scenario, the certification authorities, manufacturers and operators would collect and analyze all experience and use the experience to formulate one action plan to reduce accident/incident rates. This method, which is shown by FAA draft AC 39.XX,[3] is valuable, but is only one dimension of continuing airworthiness.

There are two major reasons that the development of look-forward processes is recommended to enhance the look-back process:

- The numbers of reported accidents/incidents have been low compared with the number of all possible accident/incident causes. Manufacturers and operators cannot imagine all the events that could occur. Thus, it is likely that a large number of prospective ("what-might-happen" or look-forward) situations have not been foreseen or have been regarded as insignificant. A prospective view is necessary in a continuing-airworthiness process but is difficult to achieve.

  Using retrospective ("what-has-happened" or look-back) data as a starting point to envision prospective scenarios has infinite possibilities and must be constrained by good decision processes (by civil aviation authorities (CAAs), manufacturers, operators and pilots' associations) if continuing-airworthiness processes are to maximize safety. Such good decision processes should incorporate a systematic identification and evaluation of precursor events to significantly enhance safety.

- The retrospective method does not address innovations and changes: more commercial aviation activity and new transportation markets, new materials, new models, new guidance and control technologies, revised training procedures, new knowledge of human capabilities, changing physical environments, and changing educational and social environments. Some changes will lead to safety enhancement; some will diminish safety.

The prospective processes can supplement the retrospective processes based on:

- Accumulation and classification of in-service experience (accidents/incidents and reliability information);

- Analysis of the accumulated data to determine the most productive ways to improve safety;

- Any processes that differentiate incident-rate data and reliability-rate data to predict increasing or diminishing rates. (Differentiation of rates that are quite variable [noisy] can give misleading indications);

- Investigation of "what-if" scenarios. All such scenarios must not be dismissed, but considering their limitless numbers, scenarios must be constrained by effective decision processes; and,

- The application of risk-evaluation technologies from other scientific fields to aviation safety. Technologies from neuroscience, epidemiology and advanced statistical methods will be of value.

### 2.3.6 Productivity Issues in Data Use

Use of data for continuing airworthiness is labor intensive because experienced engineers and analysts must control carefully the quality of data input. This usually requires manual entry of data into the database; for example, airplane makes and models — such as "B-737" and "Boeing 737" — must be entered uniformly. Most automated analyses are successful only for screening and are subject to some limitations. After an anomaly is discovered, experienced analysts must then determine the reasons for the anomaly. Knowledge of the circumstances surrounding the event being studied — in addition to analytical ability — is essential for a program to be credible and useful.

Quality assurance for safety-related data requires the following resources:

- The skill and knowledge of the people assigned to evaluation;

- Sufficient time, tools (e.g., computers, analyses, tests) and management support to perform a high-quality evaluation;

- Knowledge of the original certification premises and analyses (often, but not always needed); and,

- Access to other knowledgeable individuals as information sources, and with whom to share and compare ideas.

## 2.4 FOQA

One way to identify latent conditions is to exploit the capabilities of the digital flight data recorders (DFDRs) and sensors that are on most civil transport airplanes. Flight Safety Foundation conducted a study for FAA in 1992 of benefits that could be derived from the voluntary adoption of FOQA programs.[4]

FOQA is a process in which sensor data recorded by an airplane's DFDR during flight are easily retrieved from the airplane and analyzed with computer software. Analysts interpret data and convey the resulting information to operations and management in a timely and accurate manner, and make trend data available to the FAA to allow industry-wide analysis of trends. The advantages to such analysis include monitoring pilot performance and adequacy of pilot training, and evaluation of airplane performance, standard procedures and ground facilities.

FOQA, though acknowledged as beneficial by a majority of U.S. operators, has fallen short of its full potential as a comprehensive, integrated and universal system. A major reason for this lies within the societal and legal structure of the United States. Some information provided by industry to the federal government is available to the public under the provisions of the Freedom of Information Act (FOIA).

FOIA generally provides that any person has a right of access to certain federal agency records. This right of access is enforceable in court, except for records that are protected from disclosure by nine exemptions: (1) classified national-defense and foreign-relations information, (2) internal agency personnel rules and practices, (3) material prohibited from disclosure by another law, (4) trade secrets and other confidential business information, (5) certain interagency or intra-agency communications, (6) personnel, medical and other files involving personal privacy, (7) certain records compiled for law enforcement, (8) matters relating to the supervision of financial institutions, and (9) geological information about oil wells.

FOIA does not apply to the U.S. Congress, records of state or local governments or the courts. FOIA does not require a private organization or business to release any information directly to the public, whether it has been submitted to the government or not. Nevertheless, information submitted by private organizations or businesses to the federal government may be obtained by submitting a FOIA request, provided that the information is not a trade secret, confidential business information or protected by some other exemption.

Although efforts are under way to write legislation that would provide specific exemption of FOQA data from disclosure, the matter of data protection remains one of the major deterrents to wider adoption of this voluntary program. For some organizations, the primary concern is preventing the use of data in regulatory enforcement or in the news media.[5] Other organizations, such as the Air Line Pilots Association, International, have said that properly designed FOQA programs can overcome these concerns, but potential access to data for civil litigation has been a difficult problem impeding the growth of FOQA programs. For example, a FOQA program would deidentify collected data. (See "Aviation Safety: U.S. Efforts to Implement Flight Operational Quality Assurance Programs." *Flight Safety Digest*, July–September 1998.)

U.S. society's strong inclination toward litigation for dispute resolution, the broad reach of U.S. tort law (resulting in exposure to litigation of parties who may have had no direct involvement in an accident) and the availability of private information via the government through FOIA have created a reluctance by the private sector to share data. In many cases, there also may be a substantial lack of appreciation of the significance of precursor trends that could be identified from shared data. Effective FAA, manufacturer and airline operator educational programs may develop the level of understanding necessary for aggressive identification of precursors.

This situation is unfortunate, considering the success of routine flight data analysis programs by many airlines around the world. Their safety programs are buttressed by data, and a strong case can be made for the positive influence these programs have had on safety.

Non-U.S. operators said that they generally do not expect data submitted to regulators to become public information. Although they preserve confidentiality of some information for economic competitiveness, they were generally willing to discuss their processes and to provide data to the study team as illustrative examples.

Some U.S. operators have adapted FOQA principles to their own internal processes and have derived some benefits. Nevertheless, they lack the advantage of a broadly based FOQA system that would have a richer source of national fleet data from which to derive useful information for safety management and operational management.

FOQA is one example of a proactive, anticipatory, safety-improvement strategy. Data sharing would provide each operator a means of evaluating its own operation and continuing airworthiness programs against an industry-wide norm that would not be attributable to specific competitors. FOQA would enable qualified analysts to identify anomalies, trends and timely corrective actions.

## 2.5 New Continuing-airworthiness Issues

The following issues are significant to continuing-airworthiness processes:

### 2.5.1 Emerging Technology

During the past 40 years, the commercial aviation industry has introduced technologies such as swept wings, turbojet and turbofan engines, onboard weather radar, advanced control processes, advanced displays and digital avionics. Assessment of emerging technologies and their in-service reliability is a major goal of continuing-airworthiness programs, enabling operators to recognize trends that may indicate underlying problems before serious accidents/incidents occur.

### 2.5.2 Aging Airplanes

Overall, the safety record for air carriers has been good, as shown in Figure 4. The safety record for airplane primary structures during the past two decades has been exceptionally positive. Nevertheless, in other areas — such as newly emergent wiring problems caused by aging, or inadequately protected microcircuitry in digital avionics that might present problems in the future — the experience base and current data are insufficient to forecast all problems with newer technologies. In such specialized areas of airworthiness, improved CARE processes could make substantial safety contributions.

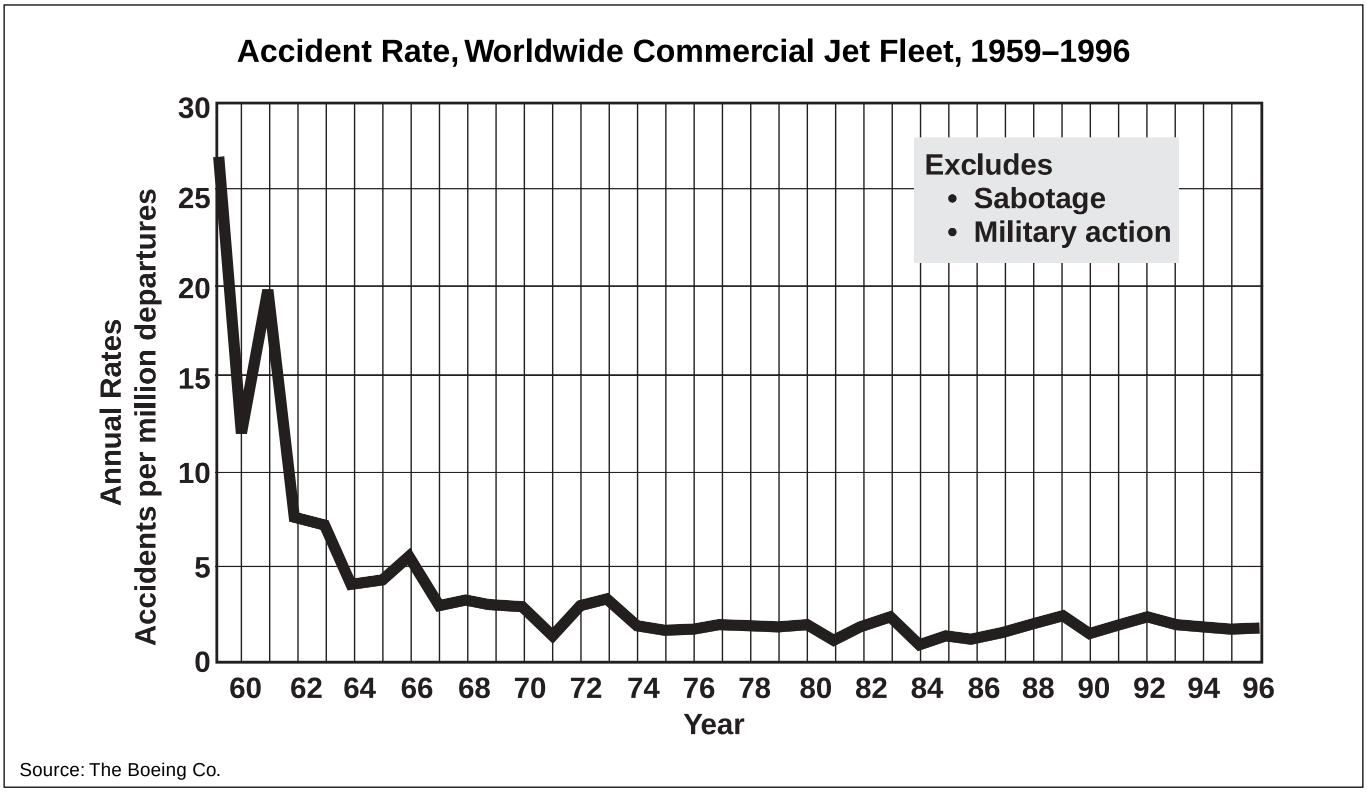
There is also a concern that complex systems may require an increasing level of maintenance as the airplanes age. Moreover, as airplanes age, they sometimes are sold to operators that do not have sufficient maintenance resources, knowledge of safety issues or commitment to a comprehensive safety program. In such situations, continuing-airworthiness programs of manufacturers and government authorities become more important. Infrastructures in some countries may not be well developed or recognizable to outsiders.

### 2.5.3 Social and Economic Issues

Cultural attitudes toward what is "safe enough" in aviation are variable. Such attitudes could become more volatile, depending on the flying public's exposure to a different quantity or quality of media reports about commercial air transport accidents. The opportunity for misinformation is great, and the public could demand solutions that would be scientifically ineffective or economically unfeasible.

Consumer demand for industry reform can be intense, and after every major commercial air transport accident, public concern about aviation safety must be addressed. Economically, the past half-century has been unusually favorable to industry growth in the United States; more than 80 percent of the population directly uses commercial air transport. Consequently, such accidents have become personally relevant to a greater proportion of the population than ever.

Figure 5 shows that a static accident rate and increased volume of traffic would combine to produce more accidents in the future.



Source: The Boeing Co.

Figure 4

Public awareness of operational details in aviation has increased gradually; thus, imprecise public explanations for accidents that formerly may have sufficed today would not be tolerated. Should the economic situation change radically or public attitudes demand substantially greater safety, the integrity of CARE will continue to be of critical importance in maintaining ridership and public confidence in the commercial air transport system.

## 2.6 Current Continuing Airworthiness

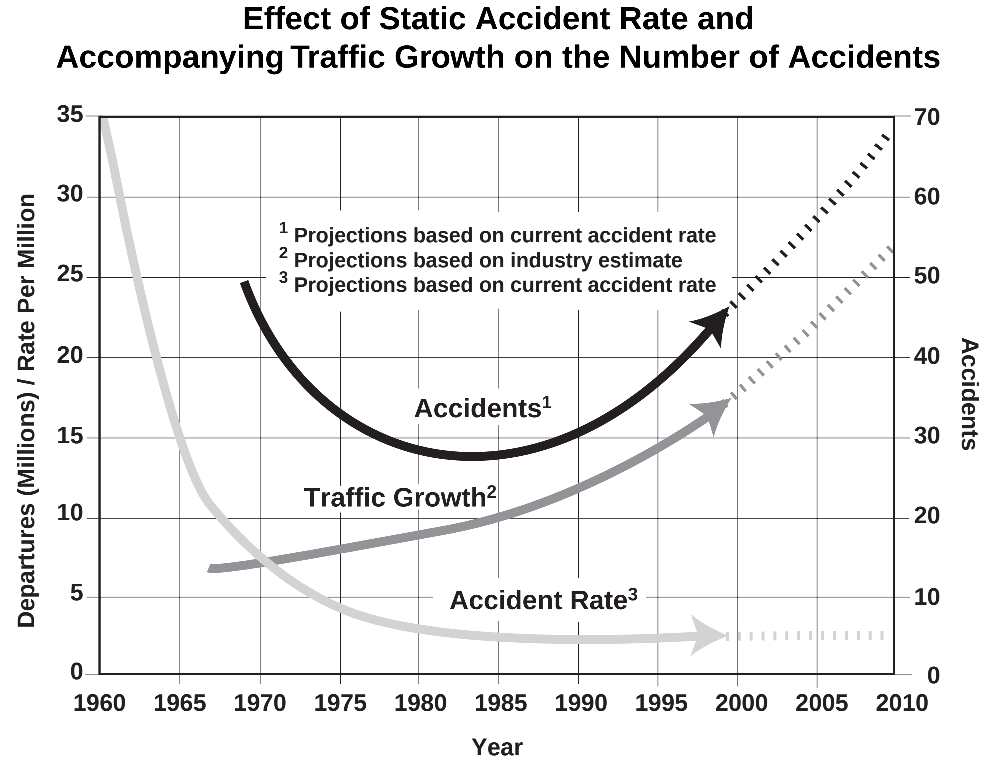
Any continuing-airworthiness program invites the following questions about its scope and boundaries:

- Is continuing airworthiness a total process, or a principal subpart of a total process?

Figure 6 shows the study team's answers to this question. The continuing-airworthiness diagram, adapted from draft material[6] being prepared by the Society of Automotive Engineers (SAE) S-18 Committee, shows a total process, including the right-hand item (disposition action plan and the associated feedback paths).

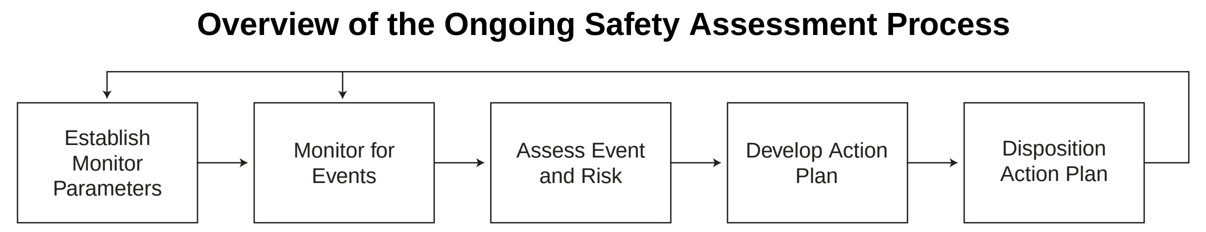
The other items (establish monitor parameters; monitor for events; assess event and risk; and develop action plan) individually have been the focus of some continuing-airworthiness programs.

- Is continuing airworthiness sufficient, or should CARE address both continuing airworthiness and improving airworthiness?


**Effect of Static Accident Rate and Accompanying Traffic Growth on the Number of Accidents**

Source: Flight Safety Foundation

**Figure 5**


**Overview of the Ongoing Safety Assessment Process**

Source: Society of Automotive Engineers S-18 Committee (from preliminary draft of Aerospace Recommended Practice 5150)

**Figure 6**

Establishment and verification of an airworthiness standard is the basis for the type-design approval of a new or derivative airplane. Although this approval process is administered carefully, the process is imperfect. Thus, monitoring of real-world service experience may reveal unrecognized problems.

The continuation/improvement viewpoint has been taken by the study team. The total process of CARE includes:

- Establishing expectations;
- Establishing monitoring parameters;
- Collecting and analyzing data;
- Analyzing events and risks;
- Developing corrective actions;
- Recommending corrective actions; and,
- Implementing and monitoring corrective actions.

Data collection and analysis are followed by decisions. Decisions generally employ a wide range of information — for aviation safety, information resulting from airworthiness data collection and analysis combined with economic, operational, historical, scheduling and political information.

Figure 6 does not attempt to account for the many other factors in decision making. These factors probably cannot be modeled as an extension to Figure 6. The reason for not accounting for decision-making factors was explained well in the review[7] of a recently published book (*The Productive Edge* by Richard K. Lester, director of the Massachusetts Institute of Technology's Industrial Performance Center): "Among the great ironies of the computer age is that information is cheap and accessible. … What is valuable is what one does with it. And the human being cannot be mechanized." This is a reminder that data collection and analysis are important, but only as the initial steps of a continuing-airworthiness process.

Continuing airworthiness involves several processes working in parallel (e.g., airline process, manufacturer process, supplier process and authority process). Ability to "look across" data or to exchange data among the processes is desirable. This ability would be enhanced if nomenclatures and methods in each of the processes were coordinated reasonably.

Figure 7 shows the complexity of the total continuing-airworthiness process and other important parallel processes. In this figure, the points shown by (1) are the significant decision points where information flowing from the data systems (4) and analysis systems (5) is joined by a wide range of other pertinent information.

### 2.7 Data-driven Methodology

Affordable, powerful data-processing technology has stimulated analysis of aviation operational data and safety data for safety improvements. Historically, regulatory authorities and operators have relied on single-event analyses more than comprehensive analysis of systems to discover safety problems. These events included accidents/incidents and, occasionally, special studies of suspected problem areas. Problems, when discovered, were corrected and the system continued to operate.

Recently, the term "proactive safety" has been used to describe an aviation-safety paradigm involving efforts to discover problems before they cause accidents/incidents. A major component of proactive safety is the use of more routine information for analysis of trends and patterns that may indicate emerging problems. Proactive safety supplements traditional safety efforts but does not replace them. FAA, for example, has introduced the Global Analysis and Information Network (GAIN), a model for proactive use of aviation data.

GAIN would use a range of aviation safety data from a variety of worldwide sources to provide a warehouse of information that could be evaluated routinely to assist in the proactive recognition of emerging patterns and trends. Advantages would include significant leveraging of knowledge, because analysts would evaluate trends across fleets and many operators. GAIN remains at the conceptual stage, but GAIN highlights a shift in thinking among aviation-safety practitioners.

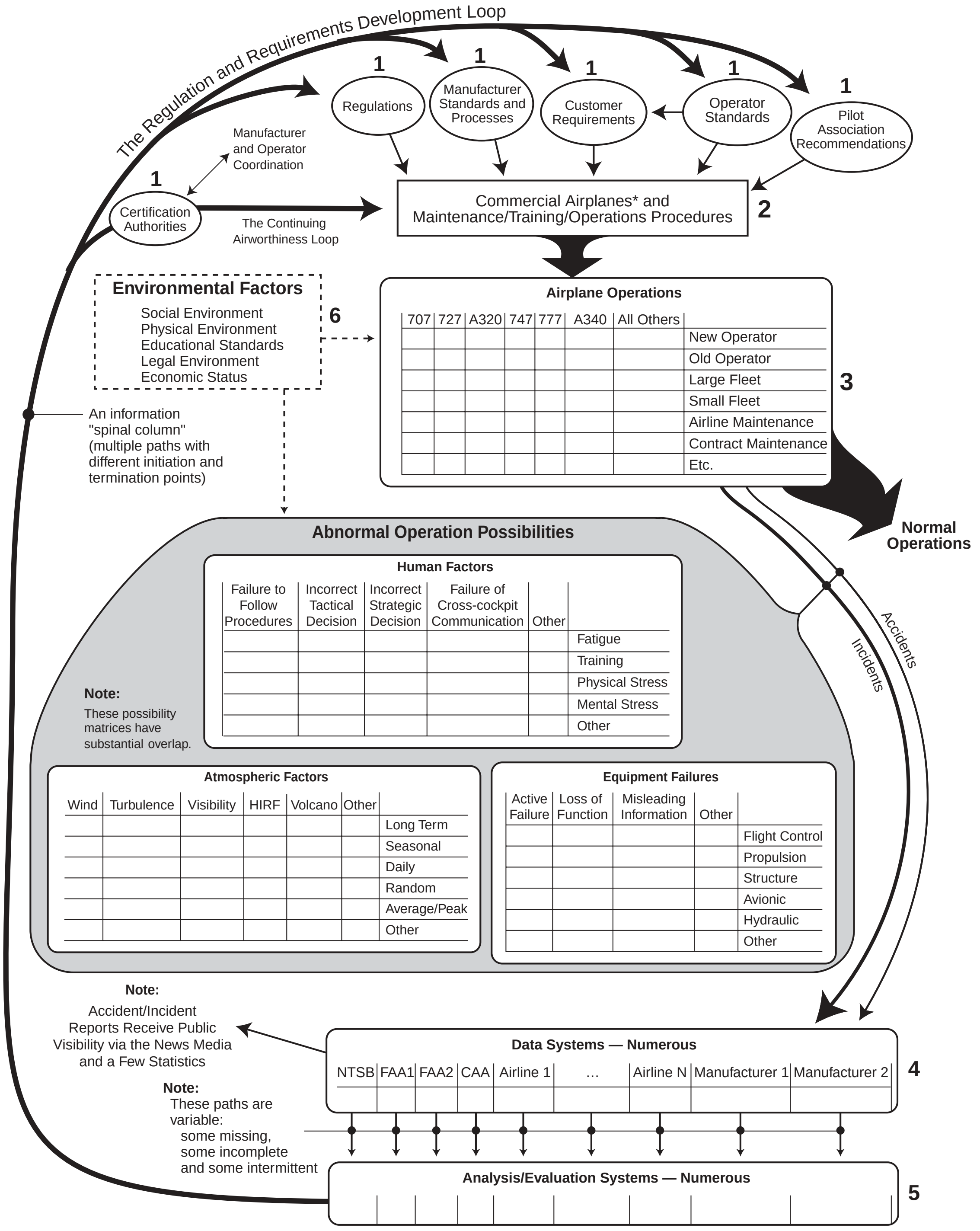
## 3 Findings

### 3.1 Continuing-airworthiness Processes in the United States

Figure 8 (page 12) shows a general overview of the continuing-airworthiness processes in the United States. They include processes that are legally defined and required and processes that exist to accomplish the objective of the aviation industry to maintain and improve safety standards. The continuing-airworthiness variables are complex but logical. The quality of the associated processes and data flows — or possible improvements by deletions, additions or quality enhancements — cannot be represented in Figure 8; quality is very difficult to evaluate.

The two inputs that drive the system are: operator in-service experience, and manufacturer type-design analyses and tests. The legally defined and/or required outputs of the system are: U.S. National Transportation Safety Board (NTSB) recommendations, FAA airworthiness directives, FAA service difficulty reports and feedback from FAA processes to FAA management to assist in program evaluations and improvements. A second set of outputs originates in operator processes and manufacturer processes. These processes are mixtures of safety-enhancement information and of information needed to improve the efficiency of operations (manufacturing and airline).

**Commercial Aviation Safety Processes**

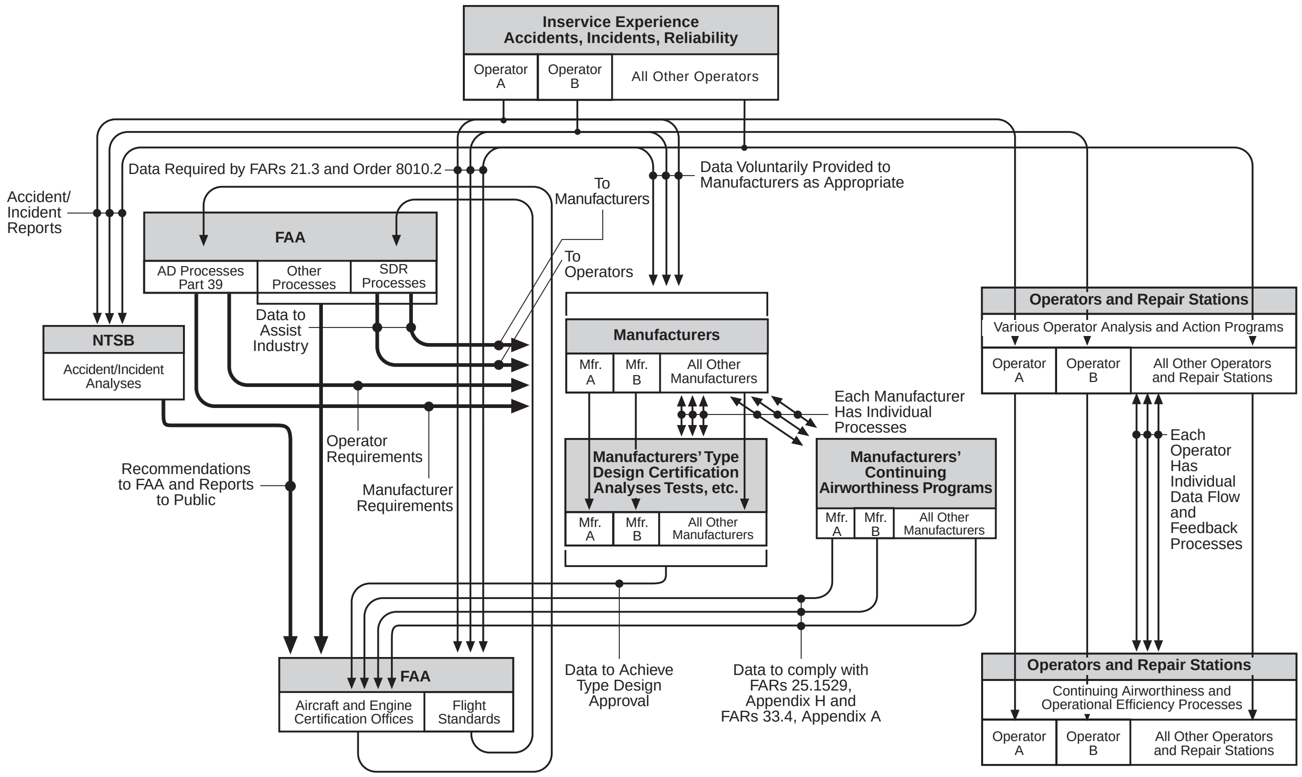


**1** Decision Points — Action or inaction based on experience
**2** Commercial Airplanes
**3** Airplane Operations
**4** Data Systems
**5** Data Analysis Systems

* U.S. Federal Aviation Regulations Part 25, Airworthiness Standards: Transport Category Airplanes
HIRF = High-intensity radiated fields

Source: Flight Safety Foundation Continuing Airworthiness Risk Evaluation (CARE) Study Team

**Figure 7**


Continuing Airworthiness Processes in the United States

FAA = U.S. Federal Aviation Administration NTSB = U.S. National Transportation Safety Board Mfr. = Manufacturer
FARs = U.S. Federal Aviation Regulations AD = Airworthiness directive SDR = Service difficulty report

Source: Flight Safety Foundation Continuing Airworthiness Risk Evaluation (CARE) Study Team

Figure 8

Regulatory authorities' risk-assessment methods differ from manufacturers' methods and operators' methods. The differences are a function of the objectives and responsibilities of the organizations. The system users generally determine the analysis method (top-down or bottom-up). In the top-down method, the analyst first seeks to identify the failure effects that could occur at the highest functional level of a system (for example, loss of transmitter output in a radio), then determines the possible system-subdivision failures modes that could produce the failure effect. In the bottom-up method, the analyst first identifies a low level where a failure could occur (for example, a radio circuit module), then determines the failure effects that could occur at a higher level of the system. There are practical advantages to each method — depending, for example, on whether system tests are being developed or whether troubleshooting of a system failure is required — and the two methods should be seen as complementary.

The study team made the following observations:

- No single organization (government or industry) can have — or should have — all of the data because there is the risk that data can be controlled and manipulated to misrepresent safety. Data interpretation by any organization should provide checks and balances that ensure innovation necessary for safety improvements. Nevertheless, there are possibilities for more data exchange or data sharing;

- Databases and data analysis-process organizations are different because of the unique needs and capabilities of each organization. For example, the manufacturer is interested especially in perfecting the airplane (for example, addressing warranty matters and dispatch reliability). The component manufacturer is interested in the reliability of individual parts. The operator is interested in reliability, safety and cost efficiency. Considerable progress toward data exchange would be achieved by standardization of database nomenclature and data-sorting categories; and,

- Computational and data-storage capabilities are large and growing. All parties in continuing airworthiness processes should be aware of problems associated with the acquisition of too much data: i.e., the “data glut” problem. Too much data is a problem because, to be used effectively, data must be categorized and analyzed by knowledgeable individuals, and independent cross-checks of conclusions often are desirable. Operators find it difficult and costly to assemble teams of knowledgeable analysts to evaluate large amounts of data. Modern computer systems can help in the data-acquisition processes and the data-analysis processes, but human resource needs are still large.

The keys to improvement in continuing-airworthiness processes will be:

- The availability and stability of highly skilled analysts; and,
- Improvements in decision processes that make practical use of data acquisition and data analysis in conjunction with economic information and social information.

### 3.1.1 U.S. Public Data

Currently, NTSB, FAA and U.S. Department of Transportation (DOT) — all U.S. federal agencies — require that specific types of information be reported by air carriers in the United States.

### 3.1.2 FAA Service Difficulty Reporting System

The FAA Flight Standards Service Difficulty Program, which operates the Service Difficulty Reporting System (SDRS) for the FAA Office of Flight Standards, has been in use since 1978. The objective of the program is to “achieve the prompt and appropriate correction of conditions adversely affecting the airworthiness of aircraft, engines, propellers, systems and components.”

Service-difficulty reports (SDRs) provide FAA with airworthiness data for planning and evaluating safety-related programs. The reporting system also provides FAA with a means for monitoring the effectiveness of self-evaluation techniques employed by some segments of the aviation industry.[8]

FAA requires that U.S. Federal Aviation Regulations (FARs) Part 121 and Part 135 air carriers, manufacturers operating under FARs Part 21, and repair stations operating under FARs Part 145 report specified failures, malfunctions or defects of specific systems that, in the opinion of the reporter, have endangered or may endanger the safe operation of an aircraft.[9] A broad variety of data must be reported, such as aircraft make and model, stage of failure, nature of failure and part identification.

These reports are submitted to the FAA principal maintenance inspector for each aircraft operator. After review, the report is forwarded to the FAA Mike Monroney Aeronautical Center in Oklahoma City, Oklahoma, U.S., where the information is entered into the SDRS.

A weekly summary report is compiled and distributed to aircraft manufacturers, air carriers, repair stations, recipients in general aviation and various FAA offices. Additional review and evaluation of the data are performed by the aeronautical center to identify trends or significant safety issues. If any are noted, the appropriate FAA office is notified and appropriate action is taken.

The mission of the Flight Standards Service Difficulty Program is to “achieve prompt and appropriate correction of conditions adversely affecting continued airworthiness of aeronautical products through the collection of service difficulty and malfunction or defect reports; their consolidation and collation in a common data bank; analysis of that data; and the rapid dissemination of trends, problems and alert information to the appropriate segments of the aviation community and FAA.”[10]

The SDRS depends heavily on full reporting of events, thorough analysis of the data and prompt feedback of safety information to the industry.

The study team’s review of SDRs found that the database contains most of the information needed to accomplish the original intent. Nevertheless, the Flight Standards Service Difficulty Program has not realized its potential because, in part, some reporters do not provide sufficient data, and data are submitted in incorrect or unusable formats. For example, large differences were noted in the frequency and accuracy of reporting for comparable events when SDR reports and data maintained by airframe manufacturers for U.S.-based airplanes were compared (see section 4.3). Some of these differences might be explained because manufacturers collect more data than required by SDRS, but the differences were so large that this alone would not explain the dichotomy. Review of individual records indicated that the SDRS database did not contain all the required events. As a result, the utility of the system has not demonstrated a level of practicality that has encouraged all data providers to participate enthusiastically.

The study team found that reporting data to the SDRS was considered a labor burden and a cost burden by some organizations. This observation was troubling to the study team.

Uneven reporting compliance was another expressed concern. If one air carrier reports all events meticulously but other carriers under-report the same events, frequency of making SDRs may distort a carrier’s apparent safety performance. The carrier with the most reports could be inaccurately characterized as “less safe.”

### 3.1.3 FAA Accident and Incident Data System

The FAA Office of Accident Investigation maintains a database called the Accident and Incident Data System

(AIDS). The majority of the incident data in the AIDS database is obtained from FAA investigations of incidents. The AIDS also imports accident data from the NTSB Accident/Incident Database.

Although the AIDS database is large, it contains little information concerning air carrier continuing airworthiness (other data from NTSB accident records).

### 3.1.4 NTSB Accident/Incident Database

The NTSB Accident/Incident Database is the official record of U.S. aviation accident/incident data and causal factors. NTSB defines "aircraft accident" as an occurrence associated with the operation of an aircraft between the time any person boards the aircraft with the intention of flight until all such persons have disembarked, and in which any person suffers death or serious injury, or in which the aircraft receives substantial damage. NTSB defines "incident" as an occurrence other than an accident, associated with the operation of an aircraft, that affects or could affect the safety of operations.

The NTSB database contains data from accidents/incidents that are relevant to continuing-airworthiness issues. NTSB has determined the issues to have been serious enough to require investigation.

## 3.2 Private Data

Databases of organizations in the private sector are varied and extensive. Such databases are maintained using different standards and for various purposes. Exchange of data is difficult among these databases because they use different software applications/different formats. Willingness to share private data depends on the specific circumstances.

### 3.2.1 Manufacturers' Databases

Common characteristics of manufacturers' databases include:

- High-quality data systems that are operated and maintained by a staff of specialists and analysts;
- High-quality data that originate from a broad variety of sources;
- Internal risk-evaluation processes that are designed to reduce their customers' risk of airworthiness-related accidents/incidents;
- Routine fleet-based analyses that are designed to recognize emerging trends at the fleet and operator level;
- Effective communication procedures to notify customers of emerging problems; and,
- Vertical and horizontal integration of data analysis into the company's product-improvement and safety-oversight processes.

Achieving this standard of database sophistication is relatively expensive and labor-intensive. The analytical procedures are comprehensive and many are automated. The staff maintaining and using these data are highly trained and qualified.

The manufacturers' databases provide important continuing-airworthiness information because they contain data about part failures and their effects on airplane safety, reliability and availability for flight. For new airplanes, these databases are complete and accurate, because owners provide complete and accurate data to the manufacturer to substantiate warranty claims. When an aging airplane is operated by a second owner or a series of owners, the manufacturer typically has more difficulty tracking data because the original warranty usually has expired and the latest owner may not provide part-failure data to the manufacturer.

Even if some owners do not routinely provide continuing-airworthiness information, all manufacturers track their airframes and attempt to capture relevant data. In many cases, the only sources of data are local field representatives who become aware of specific problems and forward data to the manufacturer. Then management can attempt to check and validate the data, and enter the data into the appropriate database.

Capturing data, sending data to management and manually coding and entering data into the database are labor-intensive and complex processes. They do result, however, in the most complete data on airplane safety and reliability for the manufacturer's product. Most manufacturers use this information for risk evaluation and share significant results with their customers and regulatory authorities.

One major benefit of the manufacturers' analytical process is the opportunity for discovery of problems within the total fleet that might be overlooked if the experience of only a few airplanes (such as the fleet of a small carrier) were examined. Thus, a large-fleet knowledge base provides greater value.

### 3.2.2 Operators' Databases

Many large operators maintain multiple database systems to support safety evaluation and management functions. The completeness and complexity of these systems vary. Although most of these systems are dedicated to business processes, many contain data usable for safety analyses and CARE.

Most of the larger operators in the United States also maintain incident-reporting databases. These systems primarily record flight-related incidents involving mechanical, human-error and other types of events. The data are proprietary and, with few exceptions, are not shared outside the operator. Some smaller operators collect incident data, but in many instances, the data are not used for routine and systematic analysis.

The use and analysis of airworthiness-related data varied greatly among the operators participating in the study. Some European air carriers conducted data collection and data analysis that matched the sophistication and comprehensiveness of the manufacturers. Like those of the manufacturers, these systems required experienced and skilled staff to manage the data and conduct the analyses, and the carriers made the management commitment to support this function.

Operators that did not have capabilities to conduct CARE or safety-data analysis cited cost as the reason. They relied on the risk evaluation and airworthiness oversight of airplane manufacturers.

To gain a better understanding of non-air carrier operators' use of airworthiness data and information, a business jet operator was contacted. This operator was considered to be representative of the newer business-charter companies operating fleets of sufficient numbers of similar airplanes for potential significance in data analysis. As with small airlines, the operators of corporate airplanes or business-charter airplanes weigh the cost of maintaining sufficient staff expertise to collect and analyze data.

For the smaller fleets, the cost may be difficult to justify in the absence of accident losses. For a larger fleet, there may be enough benefit from efficiencies gained in the operation to justify the expense. Nevertheless, unlike a smaller airline that operates airplanes manufactured by the large manufacturers, the operator of corporate jet and business-charter airplanes may receive less data analysis support from the smaller manufacturer, because of similar scale-of-operations problems. The small manufacturer's customer base is broad, with relatively small numbers of airplanes operated by any single customer. Both the manufacturer and operator therefore seem to find data-sharing mutually valuable so that fleet-wide analyses can be made of continuing airworthiness data.

Among the U.S. air carriers visited, routine risk evaluation using proprietary data on site was uncommon. There was considerable reliance on the airworthiness experience of maintenance organizations and personnel rather than on a formal internal risk-assessment process.

Most of the U.S. air carrier maintenance personnel interviewed for this study said that they relied on the airplane manufacturer to conduct routine risk-assessment activities and to provide the operator with alerts or service bulletins when problems were identified. This method appears to be satisfactory for operators that use airplanes built by the manufacturers with extensive data-collection and analysis systems. Some operators that use airplanes built by manufacturers without such systems, however, said that such support was not available.

Efforts are under way by at least one major U.S. operator to improve in-house data-analysis capabilities through the integration of many maintenance databases and management databases into a single data "warehouse." The operator believes that the ability to study problems with access to multiple internal databases through a single query will improve the efficiency and effectiveness of these systems.

One U.S. operator said that safety is a core "production value" contributing to profitability and has committed the resources necessary for analyzing all flight data and maintenance data. The airline can detect exceedances and intervene quickly to take appropriate corrections.

If an organization cannot analyze data promptly and reasonably completely, the possession of unanalyzed data may be a risk under some circumstances, for example, if data contain undetected factors that could have been involved in an accident. In postaccident litigation, the possession of unanalyzed data can be construed as a lack of due diligence on the part of an operator involved in an accident.

Many European air carriers — for example, British Airways, TAP Air Portugal, KLM Royal Dutch Airlines, Icelandair, Scandinavian Airlines System, Lufthansa German Airlines, Swissair, Air France, and Alitalia — also collect internal data about continuing airworthiness. They routinely collect in-flight data and threshold exceedance information that includes both airworthiness parameters and flight operations parameters. Although data sharing may be simpler in some European countries because of the absence of public right-to-know laws, commercial competitiveness hinders a totally free exchange.

In general, the study team found less reluctance among the European operators and other organizations contacted to freely discuss data related to continuing-airworthiness concerns. Relationships between the private companies and their respective airworthiness authorities vary among the European states, but there seemed to be a general level of comfort in sharing information among organizations primarily concerned with improving safety or reliability.

One medium-size international carrier and one large international carrier in Europe provided a greater understanding of how data usefulness could be improved. Both carriers have comprehensive and effective safety data collection and analysis processes, with incident-reporting, routine flight data analysis (e.g., FOQA), and an internal reliability data-collection and data-analysis process to monitor and oversee the quality and safety of maintenance and flight operations.

For example, flight data analysis has been part of the airlines' operations for the past 20 years or more. The larger airline samples the recorded data; the medium-size airline analyzes each flight record. Otherwise, the process is similar for both operators. Typically, after an airplane arrives at the respective airline's main base of operations, the data record is removed from the airplane and processed through an automated analytical routine. The results are then analyzed to determine if baseline performance values were exceeded.

The medium-size carrier in the study collected data from DFDRs, data from engine recorder systems, and data from flight crews on airplane performance and maintenance status. An in-house reliability and engineering staff developed, in conjunction with the airplane manufacturer, standardized routines to process the data. Any values that exceed normal values are analyzed, and corrective actions are taken. This airline was small in comparison with many other international airlines, but found that the benefits from this level of evaluation were cost effective.

The larger carrier's reliability and airworthiness database and analysis system are as sophisticated as its flight-data analysis program. The airline uses the data from the engine health-monitoring system that is provided by the manufacturer of engines. These data are generated by the engine full-authority digital electronic control, then recorded and evaluated by an analyst. Exceedances — variations from normal performance by a predetermined amount — of specific parameters are highlighted. Related maintenance and airworthiness data also are collected and analyzed by the engineering division. Analyses are conducted daily, with exceedances receiving immediate attention.

The large carrier provides monthly reliability reports for each airplane in the fleet. These reports include the following information:

- General statistics, including data on the number of airplanes, total flying hours, total flight cycles, daily utilization and average trip length;

- Systems reliability analysis, including data on technical delays and cancellations, major components causing delay, pilot reports of system failures (ATA chapters), pilot complaints (not failures) by system (ATA chapters) and a listing of technical incidents and occurrences; and,

- Powerplant reliability, including data on engine hours for the fleet, engines removed, basic failures, foreign object damage and other notable events.

Each month, management and engineering personnel review the performance of each airplane fleet during the preceding month.

The large carrier's civil aviation authority receives these monthly reports, as do the manufacturers for each airplane fleet. The airline also participates in an International Air Transport Association roundtable safety meeting — the Safety Advisory Committee that is convened every six months. Twelve air carriers share information concerning their operational experience and airworthiness-safety experience during the preceding six months.

The large carrier had the most comprehensive data collection and analysis program evaluated by the study team. Three full-time engineers were dedicated to data collection and analysis. The program has provided many benefits to the operator, and management has integrated the results into normal operations. For example, cost and downtime are reduced because problem areas are discovered before failures occur. Training also can be improved to enhance pilots' operation of the airplane.

### 3.3 FAA/Industry Data Collection and Analysis Initiatives

FAA, in collaboration with the aviation industry, is incorporating the proactive safety method to take advantage of new information-management technology that is more powerful and less expensive than technology used a few years ago. Some FAA initiatives include:

- NASDAC. The FAA Office of System Safety initiated development of the NASDAC in the early 1990s. The NASDAC's objective is to use the latest information technology to improve FAA aviation-safety decision-making capability by improving access to aviation safety information and data, enabling analysts to perform integrated queries across multiple databases. The center is staffed with analysts who train new users and help users conduct database queries. Data currently contained within the NASDAC are limited to publicly available databases. There are about 25 aviation-related databases resident in the NASDAC; and,

- Commercial Aviation Safety Team (CAST). The CAST is an industry-sponsored advisory committee that collaborates with FAA to identify the most pressing commercial aviation-safety issues and to develop effective interventions. The CAST is composed of members from the commercial-aviation community, including aircraft manufacturers, aircraft operators, pilot organizations and others.

### 3.4 Continuing Airworthiness Process Outside the United States

Outside the United States, aircraft type design-approval processes (equivalent to those in FARs Parts 21, 23, 25, 33 and others) are, in general, structured like the U.S. counterparts. There have been considerable differences in type-design regulatory details. Nevertheless, harmonization processes have appreciably reduced the number of these significant details. Harmonization was initially a Joint Aviation Authorities (JAA)-FAA initiative, but as the European Union has become more established, and as the JAA has increasingly codified its rules and regulations, JAA members and other civil aviation authorities (e.g., Canada, Australia, Brazil and Russia) have participated in the harmonization process. Specifically, the manufacturer reporting requirements (such as those in FARs Part 21) are reasonably similar, and the JAA requirements are being developed further to make them more similar to FAA regulations and to include some new and improved aspects. This work underscores the need for further harmonization of FARs Part 21 occurrence reporting among JAA, FAA and other authorities.

Operational approval standards (JAA-FAA-other authorities) require operators to report a wide range of in-service and maintenance occurrences. Their requirements have substantial differences, and efforts have been made to minimize differences by the exchange of concepts and details.

## 3.5 European Data Systems

### 3.5.1 U.K. CAA

The study team visited the Safety Data Department and the Safety Analysis Department of the U.K. CAA. This enabled the team to review the design and use of a mandatory incident-reporting system maintained by a national regulator of aviation safety. Of greatest interest was how the data were collected, how risks were graded and how data were employed in developing corrective actions.

Any operator of a public-transport aircraft registered in the United Kingdom is required to report specific types of incidents, called "occurrences." Occurrences are defined as "any incident relating to an aircraft, or any defect in or malfunctioning of an aircraft or any part or equipment of an aircraft, being an incident, malfunctioning or defect endangering, or which if not corrected would endanger, the aircraft, its occupants or any other person."[11]

Reportable occurrences include those that are related to pilots, aircraft, air traffic control or ground servicing. The U.K. CAA's objectives are:

- "To ensure that the Authority is advised of hazardous, or potentially hazardous, incidents and defects, hereafter referred to as occurrences;
- "To ensure that knowledge of these occurrences is disseminated so that other persons and organizations may learn from them; [and,]
- "To enable an assessment to be made by those concerned (whether inside or outside the Authority) of the safety implications of each occurrence both in itself and in relation to previous similar occurrences, so that they may take or initiate any necessary action."[12]

The CAA monitors the reports, and conducts analyses to discover any patterns or trends that may indicate emerging problem areas. Various types of reports from these analyses are prepared and distributed to the aviation industry within the United Kingdom. Information derived from these analyses also is used by the CAA to support safety-oversight regulatory functions. If problems are discovered, discussions are held with the involved parties, and solutions are identified. The goal of this system is not to attribute blame but to find solutions to safety problems.

CAA staff believe that organizations that are required to report incidents and mechanical events do so routinely and accurately. To a great extent, the success of the program is based on trust that the CAA will not use the data other than for safety improvement.

### 3.5.2 British Airways Safety Information System

British Airways Safety Information System (BASIS), a data collection and analysis system, originally was designed to support British Airways' internal safety processes, but has evolved into a system that can be used by other operators as subscribers under a commercial licensing agreement.

BASIS is not oriented toward airworthiness; the primary focus is operational events, especially human error. The system is of interest, however, because of a number of unique features.

The software is designed to operate on suitably equipped personal computers, thus making BASIS capabilities accessible to a wide range of users. BASIS also has a relatively simple but effective risk evaluation-analysis component that helps managers to categorize and to rank the importance of events. This feature provides a management-task list for problem resolution that is prioritized by the seriousness of the event. An especially important feature enables BASIS subscribers to share de-identified data.

The BASIS agreement requires that subscribers must contribute data to share data. This ensures that all users have a vested interest in the process. The de-identified data in this aggregate database are useful for operators to compare their own safety experience to that of other operators who share the same characteristics and operate the same type of airplane.

### 3.5.3 JAA Continuing-airworthiness Process

Appendix C (page 50) shows the principal JAA requirements and advisories. Overall, the structure of JAA requirements and FAA requirements is very similar and the intent (continuing and improving airworthiness) is identical. In details, there are many differences between the sets of requirements, which may benefit from harmonization work. The JAA situation is different from that of FAA in the following ways:

- Some operators are required to report to their individual national authorities (about 15 separate databases), and there exists no JAA scheme for combining databases into a European system. This need has been recognized and, to provide an initial level of cohesion, the following papers are under review:

- A "yellow paper"[13] prepared by the JAA Operations Committee titled "Occurrence Reporting" (Oct. 13, 1998); and,
- A paper titled "European Coordination Center for Aviation Incident Reporting Systems" (March 31, 1998).

## 3.6 Obstacles to Data Sharing

### 3.6.1 Legal Liability

The U.S. airline industry perceives a high risk of exposure to legal liability from misinterpreted or incomplete private data. There is concern that operational data will be used to prove misfeasance by the data owner, whether the allegation has merit or not.

### 3.6.2 Misinterpretation of Data

Accurate interpretation of data in aviation operations is complex and demands analysts and operational personnel who are familiar with the context in which the data were generated. In relation to other operational or maintenance activities, an event or exceedance may have an entirely different meaning and level of seriousness than might appear to an outside analyst, however competent.

This applies, to a lesser extent, to data interpretation by other operators that may have a different context, leading to a misinterpretation of the safety practices of an air carrier or manufacturer. The question is whether an outside analyst could interact with an inside analyst to identify factors that could cause misinterpretation. For that to happen, considerably more trust than now exists in the industry would have to be gained. One problem is that the outside analyst is readily accessible to the news media and plaintiffs' attorneys.

Moreover, misrepresentation of data may cause unwarranted and negative publicity for an organization and may require expenditure of considerable resources in refuting any negative misinformation.

### 3.6.3 Economic Competition

Since U.S. airline deregulation in 1978, economic competition has increased substantially among U.S. air carriers with the entry of many new carriers into the market. Deregulation also has been accompanied by the downsizing of operators' engineering departments, which had conducted internal analyses of operational and maintenance data for efficiency, reliability and safety purposes. Many carriers now depend on airframe manufacturers and engine manufacturers to analyze airworthiness data and safety data supplied by carriers. The manufacturers have the staffing required to build and maintain the required data systems, and to conduct the analysis. Many air carriers have decided that developing and maintaining a formalized, in-house airworthiness and maintenance data system, suitable for formal analytical procedures, is too expensive; thus, they rely completely on the manufacturers for this type of information.

### 3.6.4 Lack of Data-format Standardization

Individual organizations or divisions within organizations typically keep data in different formats. Additionally, reports required by FAA, e.g., those for the SDRs, lack specificity in data format. Thus, considerable data-format variation appears in the SDRs. The study team found the SDRS data and other public data to be lacking in uniformity and quality, making analysis difficult and of limited value.

Many other industries, such as the health care industry, and disciplines rely on standardized data taxonomies. For example, there is an international standard for the classification of illnesses, diseases and injuries called the International Classification of Diseases (ICD) — the 10th revision now in use is called ICD–10. This standard is widely used by clinicians, insurance companies and health care researchers. ICD is updated on a regular basis to reflect changes in diseases and diagnoses. This is an expensive, labor-intensive process. In the health care industry, however, the cost is justified by the benefit.

## 3.7 CARE Study Database Analysis

The CARE Study Database (CSD) was developed to help the study team understand the usefulness of public data in evaluating airworthiness issues. The CSD, like most data systems, is subject to many limitations. For example, FAA's SDRS database (which is the source for the majority of the data in the CSD) contains examples of poor data quality and incomplete reporting. Users of these data must be aware of these limitations and restrict their analysis and conclusions to those areas that can be supported by the data. FAA maintains multiple databases designed to support aviation-safety assessment. The following observations were made using public data in the CSD.

Table 1 shows the distribution of accidents, incidents and mechanical reports in the CSD for the 1993–1996 period. The distribution of events was relatively constant during this period.

Figure 9 and Figure 10 show the rate of these events during the period. The rates of accidents and incidents are low and have remained relatively constant during the period (Figure 9). The rate of mechanical reports in Figure 10 has decreased during the period (from 255.9 per 100,000 flight hours to 145 per 100,000 hours). The reason for the significant decrease in the rate is unknown. The estimates of the fleet exposure used in the development of these rates are included as Table 5 in Appendix A (page 43).

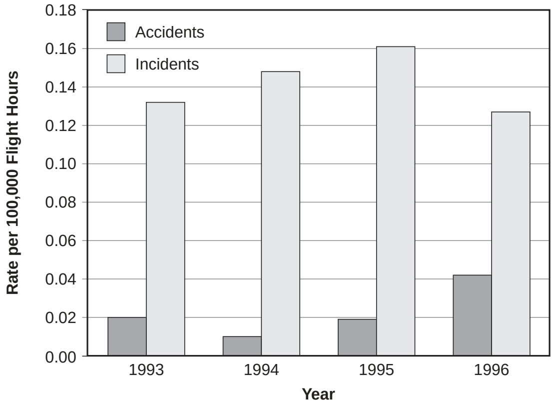
Table 2 lists the distribution of the occurrence reports' origins. The majority of reports were submitted by air carriers. Repair stations account for 0.3 percent of the total.

## Table 1
## Distribution of Accident/Incident/Mechanical Reports in CARE Study Database, 1993–1996

| | 1993 | 1994 | 1995 | 1996 |
|---|---|---|---|---|
| Accidents | 2 | 1 | 2 | 7 |
| Incidents | 12 | 15 | 17 | 21 |
| Mechanical reports | 266,370 | 260,420 | 256,600 | 254,510 |
| **Total** | **266,384** | **260,436** | **256,619** | **254,538** |

Source: Flight Safety Foundation Continuing Airworthiness Risk Evaluation (CARE) Study Team

### CARE Study Database Airworthiness-related Airplane Incidents and Accidents

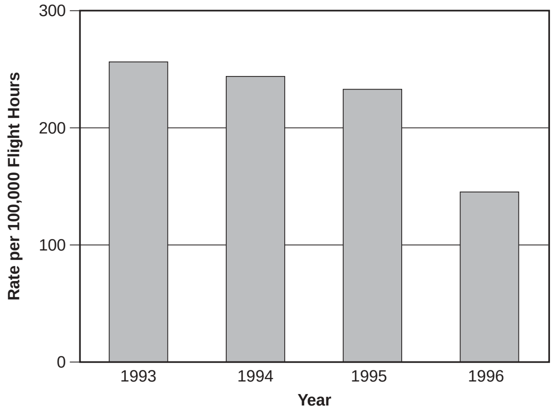


Note: These air carrier data exclude rotating equipment.

Source: Flight Safety Foundation Continuing Airworthiness Risk Evaluation (CARE) Study Team

Figure 9

### CARE Study Database Airworthiness-related Airplane Mechanical Report Rate



Note: These air carrier data exclude rotating equipment.

Source: Flight Safety Foundation Continuing Airworthiness Risk Evaluation (CARE) Study Team

Figure 10

## Table 2
## CARE Study Database Distribution of Reporters

| | Frequency | Percent |
|---|---|---|
| Air Carrier | 97,198 | 99.0 |
| Repair Station | 291 | 0.3 |
| Operator | 8 | 0.0 |
| Air Taxi | 41 | 0.0 |
| Other | 619 | 0.6 |
| **Total** | **98,157** | **99.9** |

Note: Totals may differ from other tables because of different data.

Source: Flight Safety Foundation Continuing Airworthiness Risk Evaluation (CARE) Study Team

The distribution of events by airplane type (Table 3, page 20) shows that the Boeing 727 (B-727), the McDonnell Douglas DC-9 (all derivatives) and the Boeing 737 (all derivatives) represent approximately 58 percent of all reports in the study sample. This is not surprising, because these models have been in the fleet for a long time and a very large number continue in operation. As airplanes age, they require more maintenance to remain airworthy.

The distribution of events by the ATA chapter (Table 4, page 21) shows that 41 percent of the reports involved the fuselage. The next highest frequencies were the lighting system (16 percent) and the wing structure (11 percent).

The majority of failures (Table 5, page 21) were discovered during inspection and maintenance of the airplane (77 percent). While in flight, the most common phases of failure occurrence were climb (8 percent) and cruise (5 percent).

Table 6 (page 22) shows that the majority of failures did not have associated symptoms (that is, “other” failures were 65 percent; this is not surprising because the majority of the 65 percent of failures were discovered during maintenance and inspection, when the airplane was on the ground. Other common failure symptoms include no test (15 percent), warning indications (8 percent) and false warnings (5 percent).

### Table 3
### CARE Study Database
### Distribution of Airplane Types

| | Frequency | Percent |
|---|---|---|
| Avions de Transport Regional ATR 42 | 1,447 | 1.5 |
| Avions de Transport Regional ATR 72 | 449 | 0.5 |
| Airbus A300 | 722 | 0.7 |
| Airbus A310 | 140 | 0.1 |
| Airbus A320 | 1,239 | 1.3 |
| British Aerospace ATP | 121 | 0.1 |
| British Aerospace BAe 146 | 323 | 0.3 |
| British Aerospace Jetstream | 1,512 | 1.5 |
| Boeing 707 | 66 | 0.1 |
| Boeing 727 | 25,265 | 25.7 |
| Boeing 737 | 15,139 | 15.4 |
| Boeing 747 | 5,897 | 6.0 |
| Boeing 757 | 2,686 | 2.7 |
| Boeing 767 | 1,670 | 1.7 |
| de Havilland Canada Dash 7 | 328 | 0.3 |
| de Havilland Canada Dash 8 | 1,782 | 1.8 |
| Dornier 228 | 67 | 0.1 |
| McDonnell Douglas DC-10 | 2,505 | 2.6 |
| McDonnell Douglas DC-8 | 8,035 | 8.2 |
| McDonnell Douglas DC-9 | 16,534 | 16.8 |
| McDonnell Douglas MD-11 | 382 | 0.4 |
| Embraer EMB-120 | 3,710 | 3.8 |
| Fokker F27 | 1,104 | 1.1 |
| Fokker F28 | 1,502 | 1.5 |
| Lockheed L-1011 | 3,003 | 3.1 |
| Lockheed L188 | 572 | 0.6 |
| National Aircraft Manufacturing YS-11 | 132 | 0.1 |
| Saab 340 | 1,469 | 1.5 |
| Shorts 330 | 356 | 0.4 |
| **Total** | **98,157** | **99.9** |

Note: Totals may differ from other tables because of different data.

Source: Flight Safety Foundation Continuing Airworthiness Risk Evaluation (CARE) Study Team

The most common action taken after a failure was recognized (Table 7, page 22 ) was “no action” (80 percent). This is not unexpected, because the majority of events were discovered during inspection and maintenance. Unscheduled landings (8 percent) and undefined actions (“other,” 8 percent) represent the next two most common actions.

Table 2 in Appendix A (page 39) shows the definitions of five hazard levels (Level 1–Level 5). No events in the CSD were level 5. Figure 11 (page 23) shows the Level 1 hazard rates[14] per 100,000 flight hours for the turbojet airplanes included in the CSD. The McDonnell Douglas DC-8 and DC-9 and the B-727 had the highest rates of Level 1 hazards. This is not surprising because these airplanes are the oldest in the fleet.

Figure 12 (page 23) shows the Level 2 hazard rate per 100,000 flight hours. The DC-8 and the Boeing 707 (B-707) have the highest rates. Again, this is not unexpected considering the age of these airplanes.

The Level 3 hazard rate in Figure 13 (page 24) again shows that the highest rate is associated with an older airplane.

Figure 14 (page 24) shows that the highest Level 4 hazard rates are for older airplanes, such as the B-707 and DC-8.

Figure 15 (page 25) shows the rate for all events (ranging from Level 1 to Level 4) for the airplanes in the CSD. The highest values are associated with the older airplanes, including the B-727, B-707, DC-8 and DC-9.

Table 8 (page 26) lists the airplane events by hazard level and by ATA chapter and the percentage that each hazard level represents for all hazards within that ATA chapter.

Table 9 (page 27) shows the hazard ratio for each of the ATA chapters in this analysis. The electrical-power system has the highest hazard ratio.[15]

One of the most important types of data needed for airworthiness analysis is the time in service of the failed part and the part’s TSO. Table 10 (page 27) shows that current public data sources, such as those used in the CSD, provide this information in only about 20 percent of all reports (and only 4 percent of the reports had any data about TSO). With so few reports giving this information, the study team could not perform time-in-service analysis on component failures.

## 3.8 Private and Public Database Comparisons

Evaluation of the activity information provided for three different airplanes (Figure 16, page 27) from the manufacturer and from DOT shows agreement. This is to be expected, because both the manufacturer and DOT obtain their information from the operators.

Figure 17 (page 28) shows the frequency of hydraulic-related reports submitted to the U.S. public data systems compared with those provided by the manufacturer for three sample airplanes in the fleets of U.S. operators. This manufacturer receives significantly more reports than DOT.

Nevertheless, the manufacturer might be obtaining data from customers that are not required to be reported to DOT (e.g., information relating to the warranty or other matters).

Figure 18 (page 28) shows the frequency of landing gear–related reports submitted to the U.S. public data systems compared with those received by the manufacturer for three sample airplanes in the fleets of U.S. operators. This manufacturer receives many more reports than DOT.

## Table 4
## CARE Study Database Distribution of Component Failures by ATA Chapter

| ATA Chapter | Frequency | Percent |
|---|---|---|
| 1100 PLACARDS_MARKINGS | 3 | 0.0 |
| 2100 AIR_COND_SYS | 2,099 | 2.1 |
| 2200 AUTOFLIGHT_SYS | 154 | 0.2 |
| 2300 COMM_SYS | 218 | 0.2 |
| 2400 ELEC_POWER_SYS | 1,042 | 1.1 |
| 2500 EQUIP_FURNISHINGS | 1,626 | 1.7 |
| 2600 FIRE_PROTECTION_SYS | 1,668 | 1.7 |
| 2700 FLIGHT_CNTRL_SYS | 3,233 | 3.3 |
| 2800 FUEL_SYS | 441 | 0.4 |
| 2900 HYD_POWER_SYS | 1,657 | 1.7 |
| 3000 ICE_RAIN_PROTECT_SYS | 496 | 0.5 |
| 3100 INDICAT_RECORD_SYSS | 331 | 0.3 |
| 3200 LANDING_GEAR_SYS | 8,289 | 8.4 |
| 3300 LIGHTING_SYS | 15,276 | 15.6 |
| 3400 NAVIGATION_SYS | 1,291 | 1.3 |
| 3600 PNEUMATIC_SYS | 513 | 0.5 |
| 3800 WATER_AND_WASTE_SYS | 56 | 0.1 |
| 4900 AIRBORNE_APU_SYS | 395 | 0.4 |
| 5100 STANDARD_PRACTICES_STRUCTURES | 44 | 0.0 |
| 5200 DOORS | 4,117 | 4.2 |
| 5300 FUSELAGE | 40,183 | 40.9 |
| 5400 NACELLES_PYLONS_STRUCTURE | 1,325 | 1.3 |
| 5500 EMPENNAGE_STRUCTURE_SYS | 2,508 | 2.6 |
| 5600 WINDOW_WINDSHIELD_SYS | 421 | 0.4 |
| 5700 WING_STRUCTURE | 10,771 | 11.0 |
| **Total** | **98,157** | **99.9** |

Note: Totals may differ from other tables because of different data.
ATA Chapter = Air Transport Association of America (ATA) Specification 100 code (*SPEC 100: Manufacturers Technical Data*)

Source: Flight Safety Foundation Continuing Airworthiness Risk Evaluation (CARE) Study Team

## Table 5
## CARE Study Database Distribution of Phase of Airplane Operation When Failure Discovered

| Phase | Frequency | Percent |
|---|---|---|
| Approach | 2,526 | 2.6 |
| Climb | 8,155 | 8.3 |
| Cruise | 4,665 | 4.8 |
| Descent | 698 | 0.7 |
| Inspection/maintenance | 75,082 | 76.5 |
| Landing | 792 | 0.8 |
| Not reported | 1,392 | 1.4 |
| Takeoff | 1,937 | 2.0 |
| Taxi/ground handling | 1,947 | 2.0 |
| Unknown | 961 | 1.0 |
| **Total** | **98,155** | **100.1** |

Note: Totals may differ from other tables because of different data.

Source: Flight Safety Foundation Continuing Airworthiness Risk Evaluation (CARE) Study Team

Figure 19 (page 28) shows the difference in reports submitted for navigation-system events between the U.S. public data systems and those received by the manufacturer. There is a fivefold difference in the report intake volume.

Figure 20 (page 28) shows that the manufacturer of an advanced-cockpit airplane receives more than 30 times the number of reports about flight management system failures than are submitted to DOT.

### 3.9 Public Data Analysis Findings

The tables and figures in this section highlight problems in using public data for the detailed analysis that is required for CARE. Although the exploration of these data provided some insight into overall patterns, the inconsistent and incomplete quality of the data made detailed analysis of questionable value. The majority of the data in the CSD were derived from SDRs.

Data problems included inconsistent and inadequate data in various variable fields, especially TT and TSO (Table 10, page 27). The lack of reliable time-in-service data made the

## Table 6
## CARE Study Database
## Aircraft Initial Symptom of Failure

| | Frequency | Percent |
|---|---|---|
| System affected | 12 | 0.0 |
| Electrical power loss ≥ 50% | 239 | 0.2 |
| Engine case penetration | 2 | 0.0 |
| Engine flameout | 28 | 0.0 |
| Engine stoppage | 4 | 0.0 |
| Foreign object damage | 343 | 0.3 |
| False warning | 5,262 | 5.4 |
| Flame | 111 | 0.1 |
| Flight controls affected | 743 | 0.8 |
| Flight attitude instrument | 55 | 0.1 |
| Fluid loss | 1,345 | 1.4 |
| Inadequate quality control | 310 | 0.3 |
| In flight separation | 169 | 0.2 |
| Multiple failure | 55 | 0.1 |
| No test | 14,796 | 15.1 |
| No warning indication | 516 | 0.5 |
| Other* | 63,866 | 65.1 |
| Overtemperature | 108 | 0.1 |
| Partial power loss | 10 | 0.0 |
| Significant failure report | 13 | 0.0 |
| Smoke | 2,211 | 2.3 |
| Vibration/buffet | 452 | 0.5 |
| Warning indication | 7,506 | 7.6 |
| **Total** | **98,156** | **100.1** |

* The majority of failures are discovered during maintenance and inspection, when the aircraft is on the ground.

Note: Totals may differ from other tables because of different data.

Source: Flight Safety Foundation Continuing Airworthiness Risk Evaluation (CARE) Study Team

## Table 7
## CARE Study Database, Airplane Action Taken after Failure Recognized

| | Frequency | Percent |
|---|---|---|
| Aborted approach | 393 | 0.4 |
| Aborted takeoff | 1,170 | 1.2 |
| Activate fire extinguisher | 275 | 0.3 |
| Deactivate system/circuits | 548 | 0.6 |
| Dump fuel | 39 | 0.0 |
| Emergency descent | 196 | 0.2 |
| Engine shutdown | 367 | 0.4 |
| Intentional depressurization | 10 | 0.0 |
| Manual oxygen mask deployment | 64 | 0.1 |
| No action | 78,523 | 80.0 |
| Other | 7715 | 7.9 |
| Return to block | 682 | 0.7 |
| Unscheduled landing | 8,172 | 8.3 |
| **Total** | **98,154** | **100.1** |

Note: Totals may differ from other tables because of different data.

Source: Flight Safety Foundation Continuing Airworthiness Risk Evaluation (CARE) Study Team

calculation of accurate failure rates, one of the basic components of risk evaluation, impossible.

The study team also demonstrated that retrospective determination of an event's relative seriousness (hazard level) was difficult and potentially inaccurate. Assessment of an event's hazard level requires reviewers to have extensive knowledge before assigning the hazard level that becomes part of the database. Each event is unique and requires the judgment of a subject-matter specialist.

SAE Draft Aerospace Recommended Practice 5150 will provide comprehensive guidelines on the evaluation of hazards and their ranking, but subject-matter specialists still will be required. Accurate hazard-level evaluation with public data is not amenable to automated processing. The study group believes that this observation probably is true of private data.

Nevertheless, review of public data can provide benefits. Larger trends can be discovered that may indicate underlying changes in the aviation industry. The decrease in the reporting rate concerning airworthiness-related issues for 1993–1996 (Figure 10, page 19), for example, deserves further study to determine a cause, which is unknown. Perhaps during this period, many older airplanes were retired from the fleet, and therefore, the number of airworthiness-related failures decreased. Other factors also may be operating.

One finding is that the majority of reports (77 percent, Table 5, page 21) originated from failures discovered during routine inspections; thus, the study team believes that routine inspections are discovering the majority of continuing-airworthiness issues before they cause problems in flight.

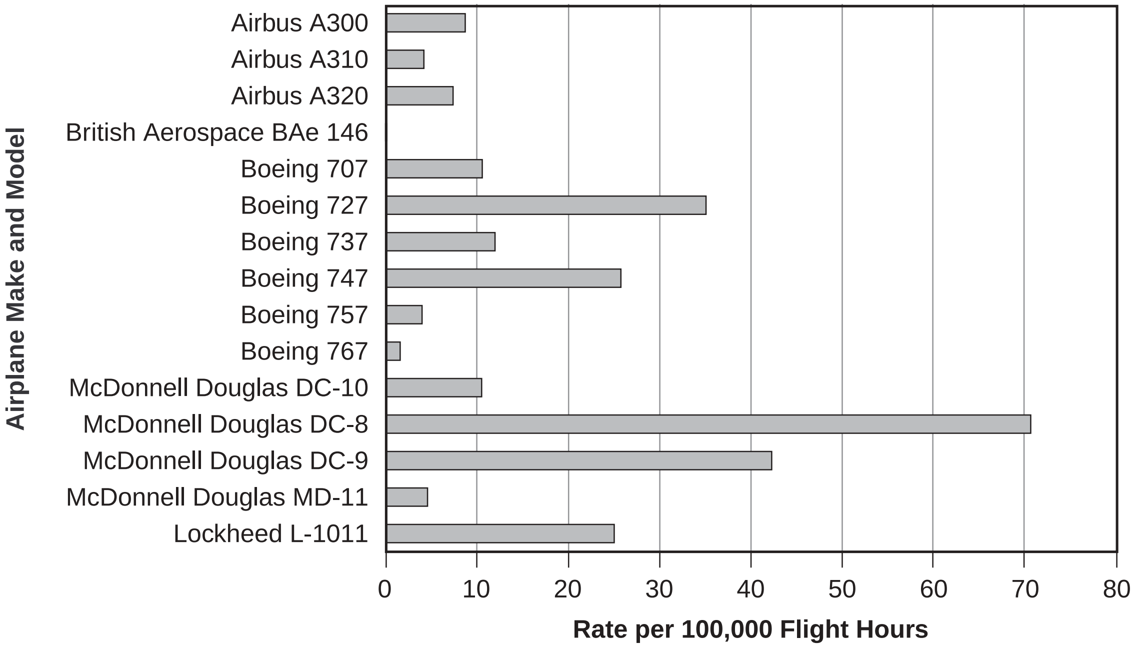
Ideally, the percentage of inspection-discovered failures would increase. If the percentage decreased, that could be an indication that current inspection procedures are not adequate to capture failures before they cause problems in flight.

Comparison of the private data collected by an airplane manufacturer to public data collected by DOT showed that the estimates of fleet flight hours for U.S. operators of three sample airplanes (Figure 16, page 27) were very similar. This finding provides some basis for accepting the estimates provided by the U.S. government as valid and suitable for rate calculations, at least for these three airplane types.

There was a discrepancy concerning the number of component failures for the study period (Figure 17, Figure 18, Figure 19 and Figure 20, page 28) between the number of reports from DOT and the number of reports from the manufacturer of the three sample airplanes. The magnitude of the discrepancies between the two sources ranged between fourfold and thirtyfold. This is a significant difference that provides evidence that manufacturers collect more data

*(continued on page 25)*

**CARE Study Database Level 1 Hazard Rate by Airplane Type, January 1993–December 1996**

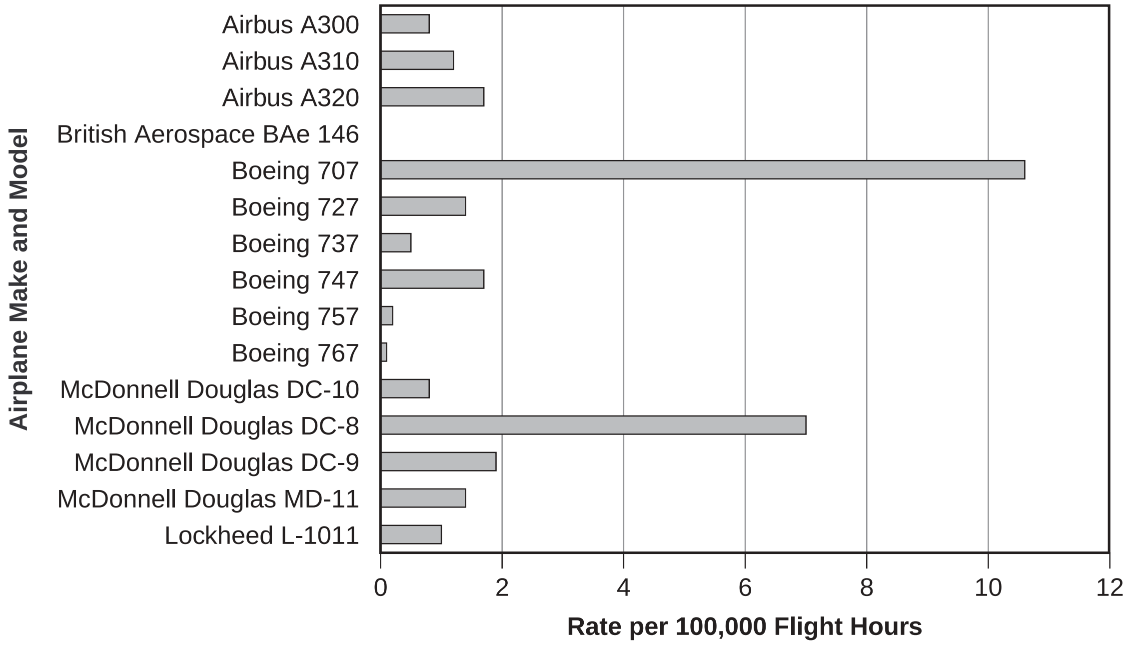


Level 1 = “No effect” hazard category in which there was no effect on the operation of the airplane

Source: Flight Safety Foundation Continuing Airworthiness Risk Evaluation (CARE) Study Team

**Figure 11**

**CARE Study Database Level 2 Hazard Rate by Airplane Type, January 1993–December 1996**

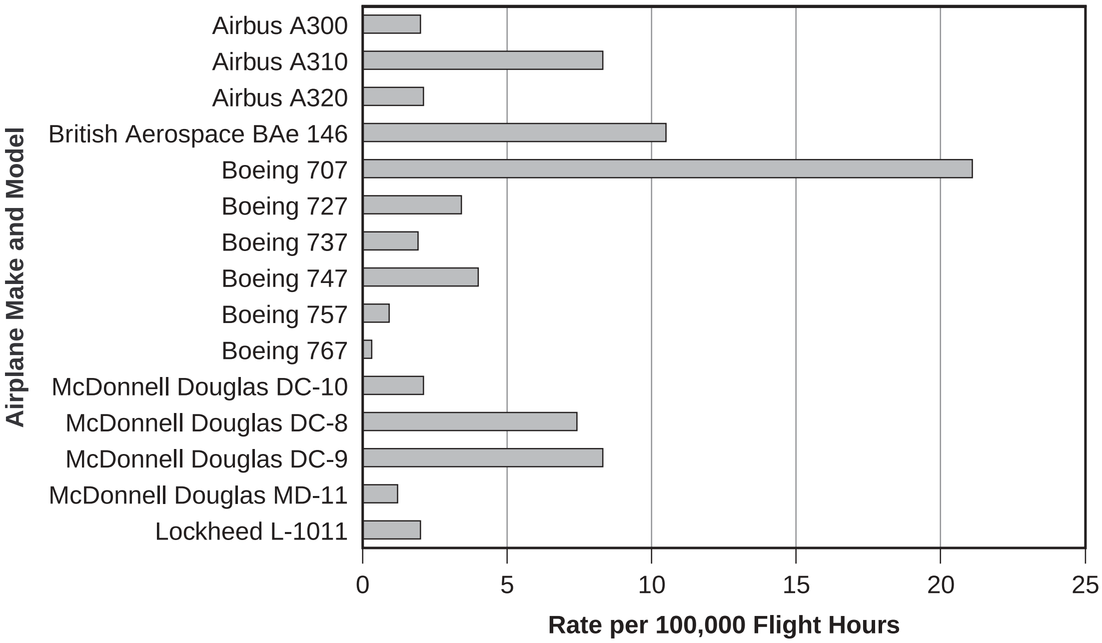


Level 2 = “Minor” hazard category in which there was little effect on crew and/or passengers

Source: Flight Safety Foundation Continuing Airworthiness Risk Evaluation (CARE) Study Team

**Figure 12**

**CARE Study Database Level 3 Hazard Rate by Airplane Type, January 1993–December 1996**

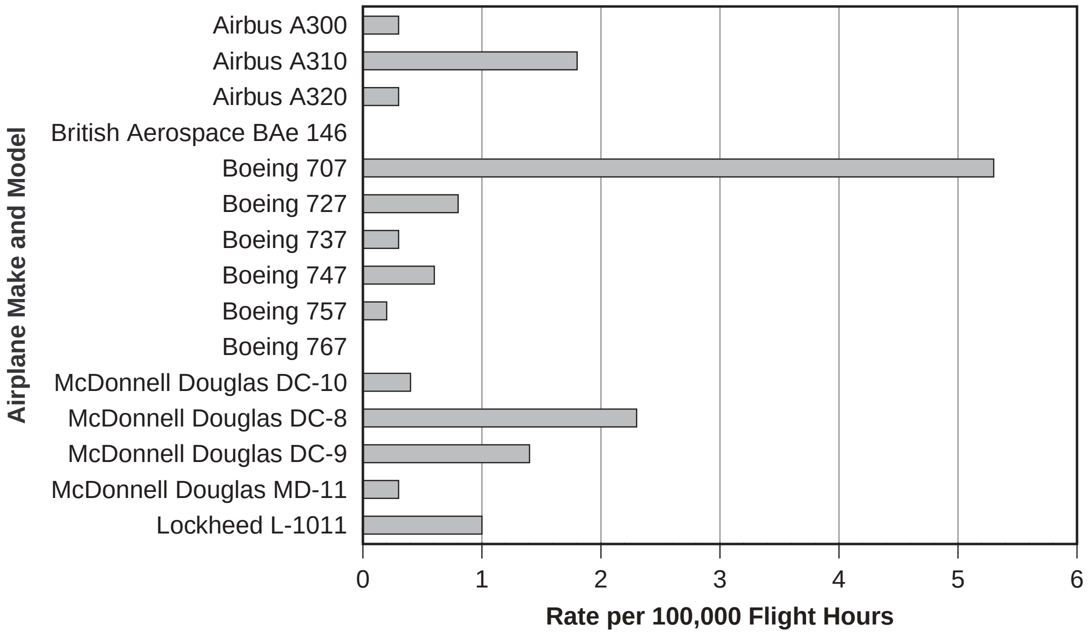


Level 3 = “Major” hazard category in which there was a major event and/or expert actions were required for resolution

Source: Flight Safety Foundation Continuing Airworthiness Risk Evaluation (CARE) Study Team

**Figure 13**

**CARE Study Database Level 4 Hazard Rate by Airplane Type, January 1993–December 1996**

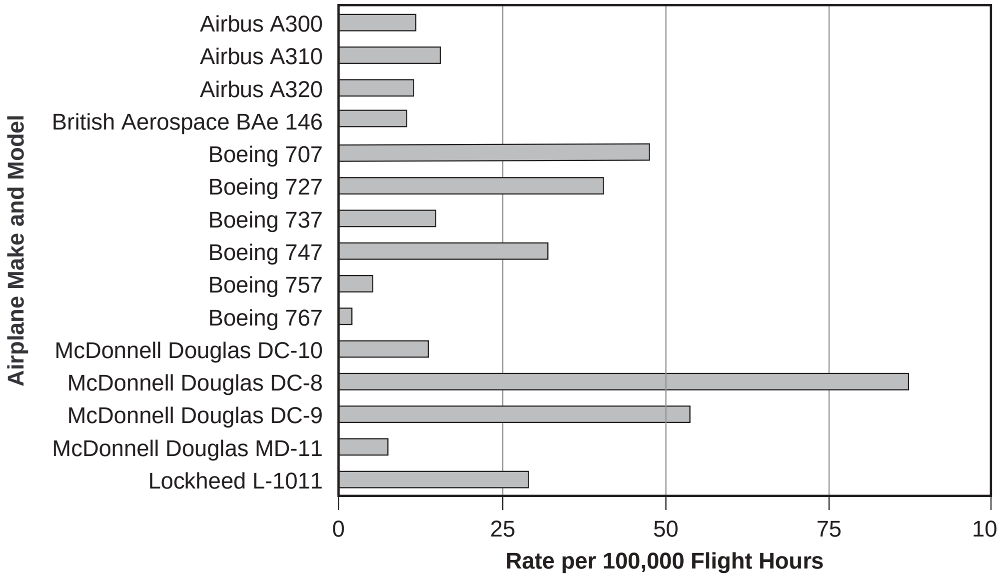


Level 4 = “Hazardous” category in which there was damage to the airplane and/or occupants were injured

Source: Flight Safety Foundation Continuing Airworthiness Risk Evaluation (CARE) Study Team

**Figure 14**

**CARE Study Database Hazard Rate (All Levels) by Airplane Type, January 1993–December 1996**



Note: Airplane events are categorized by the following hazard levels — Level 1 (no effect) for no effect on the operation of the airplane; Level 2 (minor) for little effect on crew and/or passengers; Level 3 (major) for major event with significant workload increase for pilots and/or expert actions required for resolution; Level 4 (hazardous) for damage to airplane and/or occupants injured; and, Level 5 (catastrophic) for airplane destroyed as a result of event(s) and/or multiple fatalities. The database contained no Level 5 events.

Source: Flight Safety Foundation Continuing Airworthiness Risk Evaluation (CARE) Study Team

**Figure 15**

concerning airworthiness-related events. Private data also were of better quality than those collected by DOT.

# 4 Conclusions and Recommendations

## 4.1 Proactive Method

The reactive method in aviation safety — feedback from accident investigation — should be supplemented by proactive processes that currently are being used or are being developed. Although no single source provides all the types of data required for a CARE program, multiple perspectives and data methodologies enhance safety. The lack of relevant data of uniformly high quality in the public sector reduces the likelihood that CARE will be comprehensive and fully effective for the U.S. government. Among manufacturers and airlines, however, such programs could be established and maintained, but data limitations within individual organizations and limited resources for such programs have made development difficult.

## 4.2 Data Use and Information Communication

Airworthiness data could be collected, analyzed and applied in decision making much more effectively than at present. Technological capability is not a barrier; nevertheless, many socioeconomic barriers exist.

Communication can be a significant area of weakness in safety improvement. Unequivocal instructions, procedures, notification of problems, encouragement of self reporting, and strict compliance with procedures and checklists are important, but feedback probably is most important in ensuring a safety culture in which all participants are fully engaged. Communication must be a constant interactive process. Reason[16] describes three categories of communication problems:

- System failures in which the necessary channels of communication do not exist, are not functioning or are not regularly used;

- Message failures in which the channels exist but the necessary information is not transmitted; and,

- Reception failures in which the channels exist and the right message is sent, but is misinterpreted by the recipient or arrives too late.

Management has the responsibility to ensure that safety-critical communication failures are avoided in an organization by training, procedures and oversight. Reason describes an aviation accident in which formal communications occurred between the CAA and the operator, but with little or no CAA understanding of the supervised organization. There

## Table 8
## CARE Study Database Distribution of Airplane Events by Hazard Level and ATA Chapter

| | Hazard Level | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1 | | 2 | | 3 | | 4 | |
| **ATA Chapter** | **Count** | **Row %** | **Count** | **Row %** | **Count** | **Row %** | **Count** | **Row %** |
| 1100 PLACARDS_MARKINGS | – | – | – | – | – | – | 1 | 33.3% |
| 2100 AIR_COND_SYS | 98 | 4.7% | 117 | 5.6% | 1720 | 82.1% | 160 | 7.6% |
| 2200 AUTOFLIGHT_SYS | 6 | 3.9% | 66 | 43.1% | 80 | 52.3% | 1 | .7% |
| 2300 COMM_SYS | 7 | 3.2% | 123 | 56.4% | 87 | 39.9% | 1 | .5% |
| 2400 ELEC_POWER_SYS | 83 | 8.0% | 175 | 16.9% | 479 | 46.4% | 296 | 28.7% |
| 2500 EQUIP_FURNISHINGS | 164 | 10.1% | 1089 | 67.0% | 355 | 21.8% | 17 | 1.0% |
| 2600 FIRE_PROTECTION_SYS | 101 | 6.1% | 89 | 5.3% | 1473 | 88.4% | 4 | .2% |
| 2700 FLIGHT_CNTRL_SYS | 355 | 11.0% | 1506 | 46.7% | 1340 | 41.5% | 26 | .8% |
| 2800 FUEL_SYS | 29 | 6.6% | 149 | 33.8% | 261 | 59.2% | 2 | .5% |
| 2900 HYD_POWER_SYS | 119 | 7.2% | 804 | 48.6% | 705 | 42.6% | 28 | 1.7% |
| 3000 ICE_RAIN_PROTECT_SYS | 50 | 10.2% | 120 | 24.4% | 318 | 64.6% | 4 | .8% |
| 3100 INDICAT_RECORD_SYSS | 6 | 1.8% | 15 | 4.5% | 309 | 93.4% | 1 | .3% |
| 3200 LANDING_GEAR_SYS | 1734 | 20.9% | 1935 | 23.4% | 4596 | 55.5% | 19 | .2% |
| 3300 LIGHTING_SYS | 14382 | 94.2% | 615 | 4.0% | 273 | 1.8% | 5 | .0% |
| 3400 NAVIGATION_SYS | 65 | 5.0% | 302 | 23.4% | 915 | 70.9% | 8 | .6% |
| 3600 PNEUMATIC_SYS | 46 | 9.2% | 55 | 11.0% | 395 | 78.7% | 6 | 1.2% |
| 3800 WATER_AND_WASTE_SYS | – | – | 19 | 33.9% | 36 | 64.3% | 1 | 1.8% |
| 4900 AIRBORNE_APU_SYS | 20 | 5.1% | 79 | 20.1% | 270 | 68.5% | 25 | 6.3% |
| 5100 STANDARD_PRACTICES_STRUCTURES | 1 | 2.3% | 23 | 52.3% | 20 | 45.5% | – | – |
| 5200 DOORS | 101 | 2.5% | 3051 | 74.1% | 922 | 22.4% | 43 | 1.0% |
| 5300 FUSELAGE | 99 | .2% | 39780 | 99.0% | 63 | .2% | 240 | .6% |
| 5400 NACELLES_PYLONS_STRUCTURE | 2 | .2% | 1305 | 98.5% | 14 | 1.1% | 4 | .3% |
| 5500 EMPENNAGE_STRUCTURE_SYS | 11 | .4% | 2473 | 98.6% | 15 | .6% | 9 | .4% |
| 5600 WINDOW_WINDSHIELD_SYS | 3 | .7% | 170 | 40.5% | 234 | 55.7% | 13 | 3.1% |
| 5700 WING_STRUCTURE | 32 | .3% | 10578 | 98.2% | 136 | 1.3% | 25 | .2% |

Note: Airplane events are categorized by the following hazard levels — Level 1 (no effect) for no effect on the operation of the airplane; Level 2 (minor) for little effect on crew and/or passengers; Level 3 (major) for major event with significant workload increase for pilots and/or expert actions required for resolution; Level 4 (hazardous) for damage to airplane and/or occupants injured; and, Level 5 (catastrophic) for airplane destroyed as a result of event(s) and/or multiple fatalities. The database contained no Level 5 events.
ATA Chapter = Air Transport Association of America Specification 100 code (*SPEC 100: Manufacturers Technical Data*)

Source: Flight Safety Foundation Continuing Airworthiness Risk Evaluation (CARE) Study Team

was no indication of a close working relationship between the two parties and little personal contact between the assigned inspector and counterparts at the airline.

Many organizations have demonstrated productive use of aircraft-event data in airworthiness analysis. These include manufacturers, airlines, NTSB, FAA accident investigation staff, FAA aircraft-certification offices and engine-certification offices, and the U.K. CAA Safety Analysis Department. Nevertheless, many organizations with high-quality data do not have the expertise, time or other resources needed to fully exploit the data. An independent safety data-analysis organization could perform the following steps:

- Define a strategy and an interface with the industry;
- Assemble human resources with the skills and experience required to maintain and analyze data in many formats from diverse sources;
- Structure relationships with data sources and the data-inflow processes (voluntary or mandated) that will be required;
- Establish the customers (government and private) for the analysis results, and ensure that these customers can make optimum use of the evaluation outputs; and,
- Take the actions needed to implement and maintain an ongoing process. Existing databases or database-analysis systems sometimes have essentially omitted some of these steps or have taken them in an inefficient order.

FAA Order 8040.4 (issued June 26, 1998), “Safety Risk Management,” cites the requirements for characterizing risk in aviation, one of which is the inclusion of all relevant data. The quality of these data is the key to risk characterization, and much remains to be done to provide a uniformly high quality of public data.

### Table 9
### CARE Study Database Hazard Ratios By ATA Chapter

| ATA Chapter | Hazard Ratio |
|---|---|
| 2100 AIR_COND_SYS | .076 |
| 2200 AUTOFLIGHT_SYS | .007 |
| 2300 COMM_SYS | .005 |
| 2400 ELEC_POWER_SYS | .287 |
| 2500 EQUIP_FURNISHINGS | .010 |
| 2600 FIRE_PROTECTION_SYS | .002 |
| 2700 FLIGHT_CNTRL_SYS | .008 |
| 2800 FUEL_SYS | .005 |
| 2900 HYD_POWER_SYS | .017 |
| 3000 ICE_RAIN_PROTECT_SYS | .008 |
| 3100 INDICAT_RECORD_SYSS | .003 |
| 3200 LANDING_GEAR_SYS | .002 |
| 3300 LIGHTING_SYS | .000 |
| 3400 NAVIGATION_SYS | .006 |
| 3600 PNEUMATIC_SYS | .012 |
| 3800 WATER_AND_WASTE_SYS | .018 |
| 4900 AIRBORNE_APU_SYS | .063 |
| 5100 STANDARD_PRACTICES_STRUCTURES | .000 |
| 5200 DOORS | .010 |
| 5300 FUSELAGE | .006 |
| 5400 NACELLES_PYLONS_STRUCTURE | .006 |
| 5500 EMPENNAGE_STRUCTURE_SYS | .004 |
| 5600 WINDOW_WINDSHIELD_SYS | .031 |
| 5700 WING_STRUCTURE | .002 |

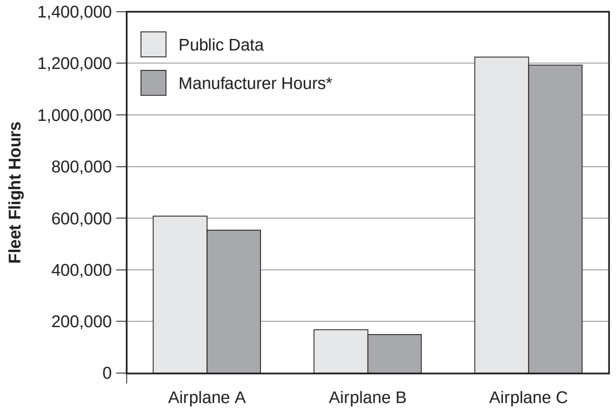
Note: Airplane events are categorized by the following hazard levels — Level 1 (no effect) for no effect on the operation of the airplane; Level 2 (minor) for little effect on crew and/or passengers; Level 3 (major) for major event with significant workload increase for pilots and/or expert actions required for resolution; Level 4 (hazardous) for damage to airplane and/or occupants injured; and, Level 5 (catastrophic) for airplane destroyed as a result of event(s) and/or multiple fatalities. The database contained no Level 5 events.

Hazard ratio = Number of hazard events ≥ Level 4 divided by total hazard events (all levels)

ATA Chapter = Air Transport Association of America Specification 100 code (*SPEC 100: Manufacturers Technical Data*)

Source: Flight Safety Foundation Continuing Airworthiness Risk Evaluation (CARE) Study Team

### Comparison of DOT and Manufacturers Fleet Flight Hours, January 1993–December 1996



* Estimated hours

DOT = U.S. Department of Transportation

Source: Flight Safety Foundation Continuing Airworthiness Risk Evaluation (CARE) Study Team

Figure 16

## 4.3 Importance of Information Feedback

Information feedback is fundamental to the proper functioning of most systems. Yet, in human-centered systems, this aspect of communication is often ignored or undervalued. Proper information feedback — such as in flight deck situational awareness, which has critical importance in crew resource management — is essential for positive results.

Similarly, the size and complexity of an organization, and its interactions with other organizations, affect information feedback. Failure to convey vital information across organizational division lines or among organizations is common.

Information-feedback failures have been cited in aviation-accident reports. For example, the failure to notify an incoming shift of maintenance technicians regarding an uncompleted repair task resulted in an airplane being dispatched with an undetected horizontal-stabilizer deficiency, leading to loss of control of the airplane and a fatal accident.

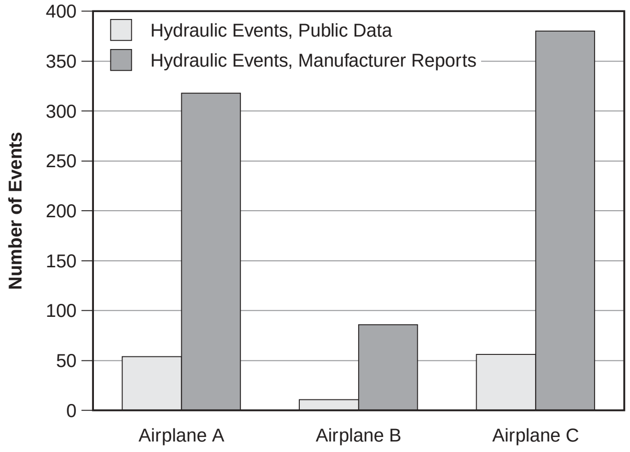
### Table 10
### CARE Study Database Number and Percentage of Reports with Completed Values for Airplane Part Time Since Overhaul or Part Total Time (Public Data)

| Type of Time | Number Completed | Percent Completed | Number Not Completed | Percent Not Completed |
|---|---|---|---|---|
| Part total time | 20,661 | 21.0% | 77,496 | 79.0% |
| Part time since overhaul | 3,702 | 3.8% | 94,455 | 96.2% |

Note: Data are from January 1993–December 1996.

Source: Flight Safety Foundation Continuing Airworthiness Risk Evaluation (CARE) Study Team

**Comparison of Public and Manufacturer Reports for Hydraulic Failures,* January 1993–December 1996**

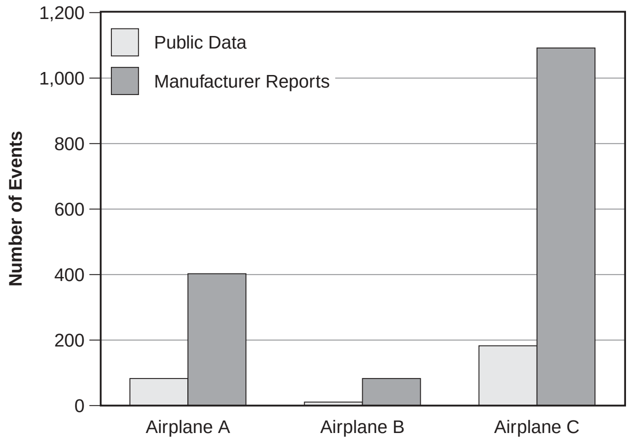


* ATA Chapter 29
ATA Chapter = Air Transport Association of America Specification 100 code (*SPEC 100: Manufacturers Technical Data*)

Source: Flight Safety Foundation Continuing Airworthiness Risk Evaluation (CARE) Study Team

**Figure 17**

**Comparison of Public and Manufacturer Reports for Landing-gear Failures,* January 1993–December 1996**

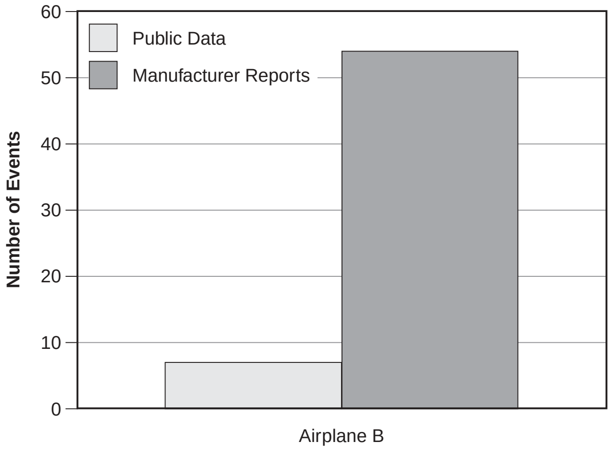


* ATA Chapter 32
ATA Chapter = Air Transport Association of America Specification 100 code (*SPEC 100: Manufacturers Technical Data*)

Source: Flight Safety Foundation Continuing Airworthiness Risk Evaluation (CARE) Study Team

**Figure 18**

**Comparison of Public and Manufacturer Reports for Navigation-system Failures,* January 1993–December 1996**

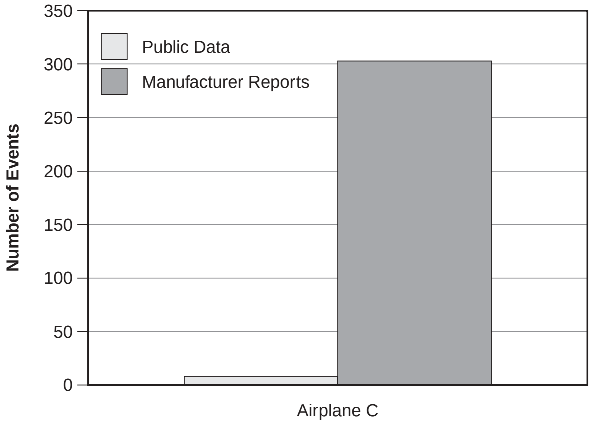


* ATA Chapter 34
ATA Chapter = Air Transport Association of America Specification 100 code (*SPEC 100: Manufacturers Technical Data*)

Source: Flight Safety Foundation Continuing Airworthiness Risk Evaluation (CARE) Study Team

**Figure 19**

**Comparison of Public and Manufacturer Reports for Flight Management System Failures* January 1993–December 1996**



* ATA Chapter 22
ATA Chapter = Air Transport Association of America Specification 100 code (*SPEC 100: Manufacturers Technical Data*)

Source: Flight Safety Foundation Continuing Airworthiness Risk Evaluation (CARE) Study Team

**Figure 20**

Another example of information-feedback failure was the failure of two airlines' maintenance departments to be aware of each other's problems with similar overhaul/repair procedures; FAA was not informed properly of the problems. This failure was among the causes of a fatal accident. The issues included aft-pylon bulkhead-flange damage and its repair, and a deviation from the manufacturer's recommended engine pylon disassembly/assembly procedures. The flange damage was repaired by one airline after receiving stress analysis approval for the repair from the manufacturer. Nevertheless, this information was not shared immediately with other airlines operating the same equipment. The procedural deviation resulted in inadvertent and undetected damage to a critical spherical bearing that subsequently failed during takeoff, resulting in the loss-of-control accident. Because the parties involved differed in their interpretations of the mechanical-reliability reporting criteria of FARs 121.703, critical information was not transmitted properly to the FAA and subsequent sharing of that information with other air carriers was not timely. During the accident investigation, NTSB expressed concern about the limitations of the reporting system and recommended that serious deficiencies in reporting requirements be corrected. NTSB also said that the air carriers could have exercised more initiative in conducting a damage-risk assessment of the unconventional pylon-maintenance procedures.

Information feedback can be critical at every level: within a maintenance department or between the regulatory authority and the operator, for example. Timely and effective communication of critical information in a can be a major contributor to improved aviation safety.

The Flight Standards Service Difficulty Program has evolved into a less effective program than intended, yet the program was established to accomplish what many data working groups recently have recommended. Attention should be given to requests that the Flight Standards Service Difficulty Program provide feedback to manufacturers and operators. In contrast, non-U.S. agencies visited by the study team managed the information-feedback process with more efficiency and effectiveness. Promptness and accuracy were the keys to success, and an unambiguous policy of requiring reports without provoking fear of penalties was common in their programs. Allocation of sufficient resources to collect, analyze and feed back the results to flight crews and maintenance groups also was common.

## 4.4 Barriers to Data Sharing

Barriers to data sharing make some improvements in the U.S. government's safety-oversight role difficult. Governmental actions generally are based on laws, orders and penalties for noncompliance or infractions.

Rules and regulations are necessary to preserve order in a complex environment. Yet, there is a possibility of diminishing returns with additional regulation, and a possibility of conflicting regulations. FAA's regular, ongoing review of regulations and standard operating procedures is one way to prevent such conflicts and a systemic overload.

Power to control information almost always involves questions of trust. Government employees may believe that trustworthiness should be assumed, based on their past responsible use of information.

One concern in the industry has been public disclosure of proprietary information through FOIA, but an environment of mistrust also may exist regarding any information that must be reported to the government. This situation might be mitigated, but not entirely avoided, by using a neutral organization to collect, aggregate and analyze airworthiness data. Reporting to such a neutral organization would require a legal basis and perhaps, government funding, which might raise questions about independence from government regulators.

Several effective systems in the aviation industry already rely entirely on voluntary reporting. Discussions of barriers to data sharing are very worthwhile, and hopefully, solutions will be developed.

## 4.5 Data Quality

Poor quality of data in public databases and private databases reduces the value of data for reliability analysis and CARE. Conversely, improvements in CARE will require higher-quality data. Nevertheless, there is a point of diminishing returns, so some improvements in data quality will not provide further improvements in airworthiness. The correlation between improvements in data quality (e.g., accuracy and reliability) and improvements in analytical insight is not proportionate.

The usefulness of public data in the United States for CARE is very limited because of the poor quality of the data. The study team found numerous weaknesses.

The data in the SDRS are, in general, incomplete. Only 20 percent of the reports in the CSD contained data on the part TT involved in the failure. Only 43 percent of the reports contained any data on the part number of the part involved. The vast majority of SDRs examined by the study team were missing relevant data in many of the data fields.

Data reliability and data validity were difficult to measure, because the study team did not have direct knowledge of the events on which the reports were based. All of the parties interviewed during this study, however, said that the present SDRS database data were of limited value for trend analysis or risk evaluation because of data-quality issues.

High-quality data are expensive because data collection and data entry require rigorous quality control. Those collecting the data, entering the data into the database and managing the database must be well-grounded in the associated database technology, aviation and data definitions.

An aggregate airworthiness database, however, would not need to be excessively complicated or comprehensive. Designers try to collect all the data they believe might be needed, not just the data that are needed to answer the basic

## Table 11
## Continuing Airworthiness — Options and Opportunities for Improvement

| Option | Involvement | Comments |
|---|---|---|
| 1. Leave processes as they now exist, including coordination and cross visibility of process. | All organizations and individuals. | Considering the need to reduce accident rates, organizations and individuals cannot endorse this option. Nevertheless, this option may result from inertia or from complicated interorganizational coordination attempts. |
| 2. No directed change of processes, but increased voluntary sharing of data and improvements in definition of data categories. | All organizations and individuals. | Aviation authorities can be facilitators of sharing processes and working to improve taxonomies. This approach can be reasonably low cost, can improve the effectiveness of many systems and can be done without questioning the integrity of organizations or individuals. |
| 3. Improve the FAA SDR system and non-U.S. counterparts. Improvements would include technical changes and giving these systems a "customer orientation" (measuring and improving the value of SDRs to government agencies, industry and individuals). | FAA and non-U.S. civil aviation authorities. | This likely will require significant cost and effort. These expenditures should be made as long as the mandatory reporting requirements of FARs Parts 121.701, 121.703, 21.3, 25 and 33 exist. |
| 4. Establish a nongovernmental worldwide data system. BASIS is an effective model. | Nongovernmental organization or organizations with financial support by governments that would not compromise the voluntary nature of the data collection and analysis. | Governments would have to be well served by organizations and processes that they do not directly control. |
| 5. Establish a worldwide government-based system to improve airworthiness. | ICAO and/or ICAO-sponsored organizations. | This would be a major step for ICAO. Perhaps an ICAO-sponsored organization would suffice and governments would have to be well served as in option 4. |
| 6. Options that are major subparts of option 1 through option 5 above. | All data contributors and users of data and analyses. | What are the information needs of government authorities, nongovernment organizations and individuals (information and timelines requirements)? |
| a. Define systems approaches. | | These standards are needed if reporting in a cooperative atmosphere is to be realized. |
| b. Establish confidentiality standards. | | Structure is all-important if organizations of various sizes and technical capabilities are to work together. |
| c. Choose a system structure that will be user friendly to governments, large private organizations and small private organizations. | | Review FARs, JARs and other national requirements and adjust as needed to be compatible with the selected mix of voluntary and required reporting. |
| d. Choose voluntary or mandatory reporting or a compatible mix. | | All reporting systems are much more effective if information contributors can obtain useful information and see how contributed information is used. |
| e. Choose effective feedback paths. | | The taxonomy should be clear, useful to large and small contributors, and useful in any organization's language. |
| f. Select a well understood and user-friendly taxonomy.<br>(Develop terminology and categories for human-error events.) | | Hardware, software and ATC terminologies are generally well developed. Much attention is needed in human-error terminology. |
| g. Choose appropriate means of communication. | | Mail, fax, email, etc. The choice may be related to confidentiality standards. |

FAA = U.S. Federal Aviation Administration SDR = Service difficulty report BASIS = British Airways Safety Information System
JARs = Joint Aviation Requirements ATC = Air traffic control ICAO = International Civil Aviation Organization
FARs = U.S. Federal Aviation Regulations

Source: Flight Safety Foundation Continuing Airworthiness Risk Evaluation (CARE) Study Team

questions that prompted creation of the database. After a database is designed and the database is put into use, users may have great difficulty making changes to collect less information. If data are not needed, this becomes apparent to those collecting, maintaining and using the data. People may believe that their efforts are wasted and that quality of input may be reduced. Ideally, a database should be designed to collect only the data that are needed for the task at hand. The resulting database is less expensive to maintain and encourages higher-quality data. Such a database can be gradually expanded or adjusted if needed; thus, adaptability should be considered in database design.

## 4.6 European Initiatives

Europe also presents some unique conditions, but each condition contains opportunities for progress in CARE. These include:

- The U.K. CAA safety-data collection and analysis system;
- BASIS, the commercial database and data analysis system developed by British Airways;
- The Airbus Industrie data-analysis system; and,
- Systems of many European operators.

The major questions seem to be: “Can JAA effectively take advantage of existing capabilities?” and “Can JAA and FAA strengthen world aviation safety through harmonization?”

## 4.7 Options and Opportunities for Improvement

The major participants in continuing-airworthiness processes now include CAAs, other government organizations, airlines, airline associations, manufacturers, manufacturer associations, pilot associations and flight attendant associations, air traffic controller associations, nongovernmental aviation safety organizations and many individuals who work in commercial aviation. Academic researchers also participate periodically in these processes. Each organization understands the importance of continuing airworthiness, and can conceive ways to improve airworthiness.

Table 11 shows the study team’s suggested upper-level view of some of these options. Comments associated with each option were based on findings of the study team.

Based on its findings, the study team makes the following recommendations:

- The private sector and the public sector must improve data quality to exploit extensive efforts underway to collect data for CARE;
- Legal protection must be implemented for shared airworthiness data;
- The SDRS must be modified, expanded or refocused so that it can be used better by FAA, airlines, manufacturers and pilot associations;
- The structure and definitions (taxonomies) used in public databases and private databases must be harmonized to enable maximum utilization of safety data on an international scale, and to minimize misinterpretation of data.♦

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13. "Yellow paper" is the means by which the Joint Aviation Authorities (JAA) issues addendums, corrections and updates to a Joint Airworthiness Requirements document. The yellow color of the paper calls attention to new information.
14. Hazard rate is the number of hazard events (Level 1, Level 2, Level 3, Level 4 or all combined as "total") that occur during a specified time period divided by the total number of flight hours for that time period, then multiplied by 100,000.
15. Hazard ratio is the conditional probability of hazard consequences or catastrophic consequences (Level 4 hazard and Level 5 hazard) given the failure of a particular system. The ratio is calculated by dividing the historical number of Level 4 hazard events and Level 5 hazard events by the total number of hazard events (that is, Level 1 through Level 5 combined).
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# Appendix A
# Goals and Methods of the CARE Study

The primary question to be answered by the Flight Safety Foundation Continuing Airworthiness Risk Evaluation (CARE) study was, "Can current information sources be used better to identify and quantify factors influencing air carrier continuing airworthiness?"

Specific goals of the study included:

- Creation of a prototype database showing baseline understanding of the historical risk of airworthiness-related accidents/incidents using a representative sample of available data;
- Application of a currently accepted risk-evaluation model for airworthiness evaluation;
- Calculation of sample malfunction rates by aircraft-system type, by aircraft type and by event seriousness derived from the data sources in the historical baseline; and,
- Identification of components required to implement effective CARE programs for smaller operators.

## 1.1 Exploratory Method

Factors affecting the continuing airworthiness of civil transport aircraft are understood in general, but there are many aspects that are not well understood. The CARE study was undertaken with acknowledgment of these uncertainties. The study team's initial methodologies underwent changes as the team encountered obstacles to information access. For this reason, the study became exploratory. The study team's research methodology was traditional for exploratory studies, as described in the following sections.

## 1.2 Evaluation of Current Procedures and Practices

Current procedures and practices in the field of continuing airworthiness were evaluated as a basis for the subsequent analysis.

### 1.2.1 Literature Review

The relevant literature was reviewed to determine the parameters of risk evaluation in aviation safety and continuing airworthiness (see Bibliography on page 32). The review included prior studies of data sources, organizations applying risk-evaluation methods and the use of risk-evaluation methods for airworthiness. References were found regarding the process of airworthiness evaluation. A number of draft documents were identified on risk assessment and continuing airworthiness. No references were found, however, regarding the implementation and application of risk-assessment procedures for continuing airworthiness for organizations such as airlines or aircraft manufacturers.

### 1.2.2 Team Visits

In addition to public data, commercial aircraft manufacturers and operators were consulted. The study team visited three manufacturers, two associations, five operators and three regulatory authorities in the United States and Europe to gather information about continuing-airworthiness processes. Interviews were conducted with several airworthiness specialists in the United States and Europe to discuss data and data management. The impetus for non-U.S. input was the reluctance of most U.S. organizations to discuss private data in detail. This reluctance was attributed to concerns about exposure to litigation, economic competition and other reasons.

The study team compared airworthiness processes and safety processes, data collection processes and the data taxonomies and data standards employed by the sample. The team formed opinions of what processes seemed to work well, and identified areas where improvements would enhance continuing airworthiness.

## 1.3 Participant Confidentiality

Significant concern exists among companies and individuals, particularly in the United States, about adverse use of private data (e.g., in litigation; economic competition; identification of organizations, aircraft and individuals; and incorrect interpretation of data). Consequently, any private data in this report are aggregated to prevent attribution to the source; public data are used without restriction.

## 1.4 CARE Study Database Development

To support the development of a prototype risk-evaluation process and to establish a baseline against which private data could be compared, a CARE Study Database (CSD) was developed using the U.S. Federal Aviation Administration (FAA) Service Difficulty Reporting System (SDRS) operated by the FAA Office of Flight Standards, the FAA Accident and Incident Data System (AIDS) and the U.S. National Transportation Safety Board (NTSB) Accident/Incident Database (see 3.1.2, 3.1.3 and 3.1.4, respectively, pages 13–14). The CSD was developed in a statistical database and analytical software application.

The following reasons for developing the CSD also were significant:

- To understand the potential and limitations of using public data for airworthiness evaluation. This baseline provides the basis for determining what could be accomplished if more complete data were available;

- To provide a basis for a comparison to a private airworthiness database; and,

- To support recommended improvements in airworthiness-data collection and analysis at the manufacturer, operator and regulatory levels.

Data in the CSD were limited to events involving U.S. Federal Aviation Regulations (FARs) Part 25 airplanes that are typically used for air carrier service. The time frame for the CSD was limited to the four-year period of January 1993–December 1996. Current CARE for rotating stock (turbine engines and auxiliary power units) is well advanced because of extended-range twin-engine operations (ETOPS), in which there is a need to demonstrate the reliability of these components. Thus, rotating-component failures were not included in this study.

The CSD relied heavily on data from the SDRS, because its primary purpose was evaluation of airworthiness-related issues. Accidents that involved maintenance-related causes or airworthiness-related causes in 1993–1996 were obtained from NTSB, and NTSB accident briefs were used as the sources of data entered into the CSD.

The data were collected and combined into one database. Frequency distributions were developed for each variable, and missing values and erroneous values were identified. The database then was validated and corrected as necessary. A number of new variables were created from other data to make analysis more efficient. They included the following:

- A uniform variable that combined the airplane manufacturer and model (e.g., Boeing 747, Airbus A320);

- A uniform variable (data field) for the year of occurrence (for example, so that “6-7-45,” “June 7, 1945” and “7 June 1945” would be recorded the same way);

- New variables that created missing values for part total time (TT) (component TT) and part time since overhaul (TSO). These values were created using an automated procedure based on linear interpolation for each value within each category defined by Air Transport Association of America (ATA) specification 100 code (ATA chapter) from *SPEC 100: Manufacturers Technical Data*; and,

- A hazard-category variable for each event. The hazard categories index the seriousness of the event with a Level 1 being the least serious and a Level 5 being the most serious (there were no Level 5 events in the data).

Appendix Table 1 (page 38) shows the major data fields contained in the CSD developed for this analysis.

Data on flight hours and cycles were obtained from two sources. The SDRS records provide variables for hours and cycles, but often these data were not present. Exposure data therefore were obtained from U.S. Department of Transportation (DOT) airline-activity reports that provide hour estimates and cycle estimates by aircraft make and model. These data were used to calculate fleet-based data that are described below. Exposure data for selected airplane models also were obtained from a major airframe manufacturer. Comparison of data was used to validate the data provided by DOT airline-activity reports.

## 1.5 Private Databases

U.S. operators and manufacturers visited by the study team discussed their methods and processes to manage private data internally, but in most cases they were unwilling to grant access to the data.

This decision redirected the study team’s visits to non-U.S. operators and manufacturers, which were not subject to the legal and public-disclosure constraints that exist in the United States. Private data were shared with the study team on site by non-U.S. organizations, making possible some comparisons of conclusions drawn from U.S. public databases used in the CSD and from non-U.S. private databases for the same-type equipment.

Access to non-U.S. private data enabled the study team to calculate high-level hazard-ratio values for selected systems using private data and exposure information. Results of these analyses are reported in the aggregate, and the manufacturers and models of the airplanes are not provided to preserve confidentiality. Systems evaluated included hydraulic, landing-gear, navigation and flight-management systems. Failure rates were calculated using public data for the subject airplanes and compared with the equivalent data collected by the private organizations.

## 1.6 CARE Study Database Analysis

### 1.6.1 Hazard-category Development

After the CSD was completed, hazard categories were developed following Society of Automotive Engineers Draft Aerospace Recommended Practice (ARP) 5150.[1] These hazard rankings — Level 1 through Level 5 — indicate relative seriousness and range from “no effect” to “catastrophic.” Appendix Table 2 (page 39) shows the types of events in each category and Appendix Table 6 (page 44) shows the hazard rate occurrence for airplanes in the CSD.

These categories are, by design, very general. The determination of an event’s hazard to any flight depends on multiple factors, including the type of airplane, the parts involved in the failure, the flight crew response and whether one or more events occurred simultaneously.

For the records in the CSD, algorithms were developed to automate the hazard-category assignment. These algorithms were based on two data fields in each record. The first data field was the initial recognition of the failure or event. Descriptors such as vibration, smoke and loss of power were reported and were used as the first step in the category assignment.

The result of the failure also was considered. This variable in the computer record included descriptors such as aborted takeoff, emergency landing and unscheduled landing. The algorithms are described in more detail in Appendix Table 3, page 40.

### 1.6.2 Failure Rates

Failure rates were calculated where possible by part type and time (cycles or hours as appropriate) for the particular airplane (see Appendix Table 4, page 41). Part or component identification was based on ATA chapters in the CSD. Using this information, failure rates were calculated by ATA chapters and by airplane types.

### 1.6.3 Trend Calculations

Trend calculations also were performed for the four-year period for selected systems on various airplanes. These calculations also were stratified (categorized) by hazard level and by year and compared with each other.

### 1.6.4 Hazard Ratios

The hazard ratio — the probability of hazardous or catastrophic consequences (Level 4 hazard and Level 5 hazard) if a particular system fails — also was determined by aircraft type and system. The ratio was calculated by correlating the historical number of Level 4 events or Level 5 events to the total number of hazard level events (Level 1, Level 2, Level 3, Level 4 and Level 5 combined).

### 1.7 CARE Study Database Limitations

The data in the prototype database were assembled for study purposes; these data have limitations and these data should not be used for program decisions or policy decisions.♦

## Reference

1. Society of Automotive Engineers International (SAE), SAE-S18 Committee. SAE Aerospace Recommended Practice (ARP) 5150 (Draft), S*afety Assessment Methods and Tools to Support Safety Management of Transport Airplanes in Commercial Service*. Warrendale, Pennsylvania, U.S.: SAE, 1998.

## Table 1
## CARE Study Database Fields and Field Descriptions

| Field Name | Field Label | Field Description |
|---|---|---|
| ACC_CAT | Type Event | Type of event (accident, incident or mechanical report) |
| ID | ID # | Unique identification number for each event in database |
| YEAR | Year | Year report filed |
| MONTH | Month | Month report filed |
| DAY | Day | Day report filed |
| LOCATION | Part Location | Location on airplane of failed part (fuselage, wings, engine, etc.) |
| OCC_DATE | Event Date? | Date event occurred |
| SUBMITTR | Reporter | Who reported event (airline, repair station, etc.) |
| STG_OPRT | Operation Stage | Stage of operation when failure noted (takeoff, cruise, approach, etc.) |
| ATA_CODE | ATA Number | Four-digit ATA chapter code for failed part |
| ACPRTNM | Part Number | Part number assigned to failed part |
| PARTNAME | Part Name | Name of failed part |
| MODELNAM | Model Name of Part | Model name from manufacturer of failed part |
| MODELDSG | Part Serial Number | Airplane manufacturer serial number of failed part |
| AC_MODEL | AC Model/Series | Reported airplane make and model |
| ENGMKMDL | Engine Make and Model | Reported engine make and model |
| PRT_LCTN | Part Location | Specific location of failed part |
| PRT_CDTN | Part Condition | Description of failed part, free-form field (broken, burned, etc.) |
| REG_NUM | Reg Number | Registration number of airplane |
| PT_TT | Part Total Time | Total time (TT) of failed part |
| PT_TSO | Part TSO | Time since overhaul (TSO) of failed part |
| MANSERNM | Manfc Ser Number | Part manufacturer serial number of part |
| AC_SERNM | AC Serial Number | Airplane serial number |
| NUM_ENG | Number of Engines | Number of engines on airplane |
| ATA_CATS | ATA Cats | Two-digit ATA chapter code of failed part |
| REMARK1 | Comment 1 | First 250-character description of failure and discovery |
| REMARK2 | Comment 2 | Second 250-character description of failure and discovery |
| REMARK3 | Comment 3 | Third 250-character description of failure and discovery |
| AC_NAME | Aircraft Make | Aircraft manufacturer name |
| FAAACGRP | AC Model | FAA description of airplane model |
| MAKEMODL | AC Make/Model | Aircraft make and model (constructed field; Boeing 747, for example) |
| ENG_NAM | Engine Manufacturer | Engine make |
| FAAENGGR | Eng Model | Engine model |
| ENGMDLNM | Engine Model | Engine model |
| PRCDRTX1 | Action Taken 1 | First action taken in response to failure |
| PRCDRTX2 | Action Taken 2 | Second action taken in response to failure |
| PRCDRTX3 | Action Taken 3 | Third action taken in response to failure |
| PRCDRTX4 | Action Taken 4 | Fourth action taken in response to failure |
| CNDTNTX1 | Indication 1 | First indication of failure |
| CNDTNTX2 | Indication 2 | Second indication of failure |
| CNDTNTX3 | Indication 3 | Third indication of failure |
| PT_TSO_1 | LINT(PT_TSO) | Missing values completed via linear interpolation for part TSO |
| PT_TT_1 | LINT(PT_TT) | Missing values completed via linear interpolation for part TT |
| AC_HOURS | Airframe Hours | Airplane total hours |
| YEAR1 | YEAR1 | Year of event |
| HAZARD | HAZARD | Hazard category (Level 1–Level 5) |

ATA chapter = Air Transport Association of America Specification 100 code (*SPEC 100: Manufacturers Technical Data*)
FAA = U.S. Federal Aviation Administration

Source: Flight Safety Foundation Continuing Airworthiness Risk Evaluation (CARE) Study Team

## Table 2
## CARE Study Database Hazard Levels

| Level | Description | Sample Damage |
|---|---|---|
| 5 | Catastrophic | Airplane destroyed as result of event(s) and/or multiple fatalities |
| 4 | Hazardous | Damage to airplane and/or occupants injured |
| 3 | Major | Major event, significant workload increase for pilots and/or expert actions required for resolution |
| 2 | Minor | Little effect on crew and/or passengers |
| 1 | No Effect | No effect on the operation of the airplane |

Source: Flight Safety Foundation Continuing Airworthiness Risk Evaluation (CARE) Study Team

**Table 3**
**Hazard-categorization Algorithm**

```
IF
PRCDRTX1 =NONE OR
PRCDRTX1 = OTHER OR
PRCDRTX2 =NONE OR
PRCDRTX2 = OTHER OR
PRCDRTX3 =NONE OR
PRCDRTX3 = OTHER OR
PRCDRTX4 =NONE OR
PRCDRTX4 = OTHER
HAZARD=1.
EXECUTE.

IF
PRCDRTX1 =RETURN TO BLOCK OR
PRCDRTX2 = RETURN TO BLOCK OR
PRCDRTX3 =RETURN TO BLOCK OR
PRCDRTX4 = RETURN TO OR
CNDTNTX1 = FLT CONT EFFECTED OR
CNDTNTX2 = FLT CONT AFFECTED OR
CNDTNTX3 = FLT CONT AFFECTED OR
CNDTNTX1 = FLT ATTITUDE INST OR
CNDTNTX2 = FLT ATTITUDE INST OR
CNDTNTX3 = FLT ATTITUDE INST OR
CNDTNTX1 = FLUID LOSS OR
CNDTNTX2 = FLUID LOSS OR
CNDTNTX3 = FLUID LOSS OR
CNDTNTX1 = OTHER OR
CNDTNTX2 = OTHER OR
CNDTNTX3 = OTHER OR
CNDTNTX1 = F.O.D OR
CNDTNTX2 = F.O.D OR
CNDTNTX3 = F.O.D OR
CNDTNTX1 = FLAME OR
CNDTNTX2 = FLAME OR
CNDTNTX3 = FLAME
HAZARD=2.
EXECUTE.

IF
PRCDRTX1 =ABORTED APPROACH OR
PRCDRTX2 = ABORTED APPROACH OR
PRCDRTX3 =ABORTED APPROACH OR
PRCDRTX4 =ABORTED APPROACH OR
PRCDRTX1 =UNSCHEDULED LANDING OR
PRCDRTX2 =UNSCHEDULED LANDING OR
PRCDRTX3 =UNSCHEDULED LANDING OR
PRCDRTX4 =UNSCHEDULED LANDING OR
PRCDRTX1 =ABORTED TAKEOFF OR
PRCDRTX2 =ABORTED TAKEOFF OR
PRCDRTX3 =ABORTED TAKEOFF OR
PRCDRTX4 =ABORTED TAKEOFF OR
PRCDRTX1 =ACTIVATE FIRE EXTINGUISHER OR
PRCDRTX2 =ACTIVATE FIRE EXTINGUISHER OR
PRCDRTX3 =ACTIVATE FIRE EXTINGUISHER OR
PRCDRTX4 =ACTIVATE FIRE EXTINGUISHER OR
PRCDRTX1 =DUMP FUEL OR
PRCDRTX2 =DUMP FUEL OR
PRCDRTX3 =DUMP FUEL OR
PRCDRTX4 =DUMP FUEL OR
PRCDRTX1 =ENGINE SHUTDOWN OR
PRCDRTX2 =ENGINE SHUTDOWN OR
PRCDRTX3 =ENGINE SHUTDOWN OR
PRCDRTX4 =ENGINE SHUTDOWN OR
PRCDRTX1 =INTENTIONAL DEPRESSURE OR
PRCDRTX2 =INTENTIONAL DEPRESSURE OR
PRCDRTX3 =INTENTIONAL DEPRESSURE OR
PRCDRTX4 =INTENTIONAL DEPRESSURE OR
PRCDRTX1 =MANUAL 02 MASK OR
PRCDRTX2 =MANUAL 02 MASK OR
PRCDRTX3 =MANUAL 02 MASK OR
PRCDRTX4 =MANUAL 02 MASK OR
CNDTNTX1 =INFLIGHT SEPERATION OR
CNDTNTX2 =INFLIGHT SEPERATION OR
CNDTNTX3 =INFLIGHT SEPERATION OR
CNDTNTX1 =OVER TEMP OR
CNDTNTX2 =OVER TEMP OR
CNDTNTX3 =OVER TEMP OR
CNDTNTX1 =AFFECT SYSTEMS OR
CNDTNTX2 =AFFECT SYSTEMS OR
CNDTNTX3 =AFFECT SYSTEMS OR
CNDTNTX1 =SMOKE2 OR
CNDTNTX2 =SMOKE OR
CNDTNTX3 =SMOKE OR
CNDTNTX1 =ENGINE CASE PENETRATION OR
CNDTNTX2 =ENGINE CASE PENETRATION OR
CNDTNTX3 =ENGINE CASE PENETRATION OR
CNDTNTX1 =ENGINE FLAMEOUT OR
CNDTNTX2 =ENGINE FLAMEOUT OR
CNDTNTX3 =ENGINE FLAMEOUT OR
CNDTNTX1 =ENGINE STOPPAGE OR
CNDTNTX2 =ENGINE STOPPAGE OR
CNDTNTX3 =ENGINE STOPPAGE OR
CNDTNTX1 =FALSE WARNING OR
CNDTNTX2 =FALSE WARNING OR
CNDTNTX3 =FALSE WARNING
HAZARD=3.
EXECUTE

IF
PRCDRTX1 =EMERG DESCENT OR
PRCDRTX2 =EMERG DESCENT OR
PRCDRTX3 =EMERG DESCENT OR
PRCDRTX4 =EMERG DESCENT OR
CNDTNTX1 =INADEQUATE QC OR
CNDTNTX2 =INADEQUATE QC OR
CNDTNTX3 =INADEQUATE QC OR
CNDTNTX1 =SIGNIFICANT FAILURE OR
CNDTNTX2 =SIGNIFICANT FAILURE OR
CNDTNTX3 =SIGNIFICANT FAILURE OR
CNDTNTX1 =50% ELECT. POWER OR
CNDTNTX2 =50% ELECT. POWER OR
CNDTNTX3 =50% ELECT. POWER
HAZARD=4.
EXECUTE.
```

Source: Flight Safety Foundation Continuing Airworthiness Risk Evaluation (CARE) Study Team

## Table 4
## Component Time Completion by ATA Chapter

| ATA Chapter | | Part Time Since Overhaul | Part Total Time |
|---|---|---|---|
| 2100 AIR_COND_SYS | Mean | 6,770.09 | 17,856.00 |
| | N | 230 | 411 |
| | Percent of Total Sum | 3.5% | 1.0% |
| 2200 AUTOFLIGHT_SYS | Mean | 6,129.33 | 29,800.83 |
| | N | 24 | 41 |
| | Percent of Total Sum | .3% | .2% |
| 2300 COMM_SYS | Mean | 3,950.71 | 14,496.00 |
| | N | 7 | 21 |
| | Percent of Total Sum | .1% | .0% |
| 2400 ELEC_POWER_SYS | Mean | 3,314.88 | 16,164.69 |
| | N | 255 | 348 |
| | Percent of Total Sum | 1.9% | .7% |
| 2500 EQUIP_FURNISHINGS | Mean | 4,104.75 | 24,048.14 |
| | N | 254 | 346 |
| | Percent of Total Sum | 2.4% | 1.1% |
| 2600 FIRE_PROTECTION_SYS | Mean | 5,802.53 | 27,378.97 |
| | N | 40 | 211 |
| | Percent of Total Sum | .5% | .8% |
| 2700 FLIGHT_CNTRL_SYS | Mean | 7,159.36 | 18,311.21 |
| | N | 319 | 775 |
| | Percent of Total Sum | 5.2% | 1.9% |
| 2800 FUEL_SYS | Mean | 5,543.74 | 19,033.56 |
| | N | 19 | 78 |
| | Percent of Total Sum | .2% | .2% |
| 2900 HYD_POWER_SYS | Mean | 5,033.06 | 15,717.87 |
| | N | 159 | 344 |
| | Percent of Total Sum | 1.8% | .7% |
| 3000 ICE_RAIN_PROTECT_SYS | Mean | 3,374.81 | 15,044.95 |
| | N | 69 | 147 |
| | Percent of Total Sum | .5% | .3% |
| 3100 INDICAT_RECORD_SYSS | Mean | 5,149.27 | 12,024.67 |
| | N | 37 | 78 |
| | Percent of Total Sum | .4% | .1% |
| 3200 LANDING_GEAR_SYS | Mean | 5,692.31 | 18,878.58 |
| | N | 641 | 1465 |
| | Percent of Total Sum | 8.3% | 3.7% |
| 3300 LIGHTING_SYS | Mean | 4,278.83 | 15,706.67 |
| | N | 278 | 740 |
| | Percent of Total Sum | 2.7% | 1.5% |
| 3400 NAVIGATION_SYS | Mean | 3,723.02 | 14,605.84 |
| | N | 293 | 515 |
| | Percent of Total Sum | 2.5% | 1.0% |
| 3600 PNEUMATIC_SYS | Mean | 3,494.21 | 24,255.55 |
| | N | 24 | 64 |
| | Percent of Total Sum | .2% | .2% |
| 3800 WATER_AND_WASTE_SYS | Mean | – | 28,952.75 |
| | N | – | 4 |
| | Percent of Total Sum | – | .0% |

ATA Chapter = Air Transport Association of America Specification 100 code (*SPEC 100: Manufacturers Technical Data*)

## Table 4
## Component Time Completion by ATA Chapter *(continued)*

| ATA Chapter | | Part Time Since Overhaul | Part Total Time |
|---|---|---|---|
| 4900 AIRBORNE_APU_SYS | Mean | 4,018.28 | 17,566.14 |
| | N | 87 | 144 |
| | Percent of Total Sum | .8% | .3% |
| 5200 DOORS | Mean | 14,004.60 | 35,373.47 |
| | N | 65 | 733 |
| | Percent of Total Sum | 2.1% | 3.4% |
| 5300 FUSELAGE | Mean | 38,109.00 | 43,689.55 |
| | N | 563 | 10,991 |
| | Percent of Total Sum | 48.6% | 63.7% |
| 5400 NACELLES_PYLONS_STRUCTURE | Mean | 23,080.56 | 39,129.31 |
| | N | 32 | 328 |
| | Percent of Total Sum | 1.7% | 1.7% |
| 5500 EMPENNAGE_STRUCTURE_SYS | Mean | 25,438.40 | 45,681.84 |
| | N | 40 | 536 |
| | Percent of Total Sum | 2.3% | 3.2% |
| 5600 WINDOW_WINDSHIELD_SYS | Mean | 8,608.33 | 12,641.26 |
| | N | 40 | 116 |
| | Percent of Total Sum | .8% | .2% |
| 5700 WING_STRUCTURE | Mean | 25,928.12 | 47,191.19 |
| | N | 226 | 2,225 |
| | Percent of Total Sum | 13.3% | 13.9% |
| Total | Mean | 11,926.83 | 36,480.68 |
| | N | 3,702 | 20,661 |
| | Percent of Total Sum | 100.0% | 100.0% |

ATA Chapter = Air Transport Association of America Specification 100 code (*SPEC 100: Manufacturers Technical Data*)

Source: Flight Safety Foundation Continuing Airworthiness Risk Evaluation (CARE) Study Team

## Table 5
## CARE Study Database Airplane Fleet Exposure Estimates
## January 1993–December 1996

| Airplane Make and Model | Departures | Hours | Trip Length |
|---|---:|---:|---:|
| Avions de Transport Regional ATR 42 | 599,609.00 | 525,466.00 | 0.88 |
| Avions de Transport Regional ATR 72 | 315,686.00 | 298,228.00 | 0.94 |
| Airbus A300 | 239,596.00 | 607,869.00 | 2.54 |
| Airbus A310 | 41,622.00 | 167,958.00 | 4.04 |
| Airbus A320 | 533,607.00 | 1,223,937.00 | 2.29 |
| British Aerospace BAe 146 | 10,403.00 | 9,536.00 | 0.92 |
| British Aerospace ATP | 57,671.00 | 41,240.00 | 0.72 |
| British Aerospace Jetstream | 393,004.00 | 273,122.00 | 0.69 |
| Boeing 707 | 7,265.00 | 18,922.00 | 2.60 |
| Boeing 727 | 4,088,489.00 | 6,505,223.00 | 1.59 |
| Boeing 737 | 8,723,171.00 | 11,464,918.00 | 1.31 |
| Boeing 747 | 347,579.00 | 2,197,089.00 | 6.32 |
| Boeing 757 | 2,066,122.00 | 5,031,551.00 | 2.44 |
| Boeing 767 | 678,108.00 | 8,694,937.00 | 12.82 |
| de Havilland Canada Dash 7 | 19,187.00 | 10,095.00 | 0.53 |
| de Havilland Canada Dash 8 | 359,477.00 | 242,981.00 | 0.68 |
| Dornier 228 | 520.00 | 1,106.00 | 2.13 |
| McDonnell Douglas DC-10 | 565,854.00 | 2,046,943.00 | 3.62 |
| McDonnell Douglas DC-8 | 415,944.00 | 1,004,511.00 | 2.42 |
| McDonnell Douglas DC-9 | 3,050,013.00 | 3,436,293.00 | 1.13 |
| McDonnell Douglas MD-11 | 106,892.00 | 654,222.00 | 6.12 |
| Embraer EMB-120 | 838,204.00 | 835,257.00 | 1.00 |
| Fokker F27 | 18,266.00 | 12,858.00 | 0.70 |
| Fokker F28 | 6,232.00 | 5,604.00 | 0.90 |
| Lockheed L-1011 | 334,181.00 | 1,143,354.00 | 3.42 |
| Lockheed L188 | 15,109.00 | 33,496.00 | 2.22 |
| National Aircraft Manufacturing YS-11 | 547.00 | 790.00 | 1.44 |
| Saab 340 | 551,821.00 | 500,150.00 | 0.91 |
| Shorts 330 | 688.00 | 550.00 | 0.80 |

Source: U.S. Department of Transportation Bureau of Transportation Statistics. Form 41: Traffic Statistics — Table T-2

## Table 6
## Hazard Rate Occurrence per 100,000 Hours of Airplane Flight Time
## January 1993–December 1996

| Airplane Make and Model | Level 1 Hazard Rate | Level 2 Hazard Rate | Level 3 Hazard Rate | Level 4 Hazard Rate | Total Hazard Rate |
|---|---|---|---|---|---|
| Avions de Transport Regional ATR 42 | 24.00 | 1.5 | 6.1 | 1.1 | 32.7 |
| Avions de Transport Regional ATR 72 | 12.70 | .7 | .7 | 2.3 | 16.4 |
| Airbus A300 | 8.70 | .8 | 2.0 | .3 | 11.8 |
| Airbus A310 | 4.20 | 1.2 | 8.3 | 1.8 | 15.5 |
| Airbus A320 | 7.40 | 1.7 | 2.1 | .3 | 11.5 |
| British Aerospace BAe 146 | .00 | .0 | 10.5 | .0 | 10.5 |
| British Aerospace ATP | 26.70 | 9.7 | 9.7 | 2.4 | 48.5 |
| British Aerospace Jetstream | 15.70 | 17.9 | 54.6 | 8.4 | 96.7 |
| Boeing 707 | 10.60 | 10.6 | 21.1 | 5.3 | 47.6 |
| Boeing 727 | 35.10 | 1.4 | 3.4 | .8 | 40.6 |
| Boeing 737 | 12.00 | .5 | 1.9 | .3 | 14.8 |
| Boeing 747 | 25.80 | 1.7 | 4.0 | .6 | 32.1 |
| Boeing 757 | 4.00 | .2 | .9 | .2 | 5.3 |
| Boeing 767 | 1.60 | .1 | .3 | .0 | 2.0 |
| de Havilland Canada Dash 7 | 198.10 | 29.7 | 79.2 | .0 | 307.1 |
| de Havilland Canada Dash 8 | 53.90 | 13.2 | 28.8 | 3.7 | 99.6 |
| Dornier 228 | 180.80 | 271.2 | 813.7 | .0 | 1,265.8 |
| McDonnell Douglas DC-10 | 10.50 | .8 | 2.1 | .4 | 13.7 |
| McDonnell Douglas DC-8 | 70.70 | 7.0 | 7.4 | 2.3 | 87.3 |
| McDonnell Douglas DC-9 | 42.30 | 1.9 | 8.3 | 1.4 | 53.9 |
| McDonnell Douglas MD-11 | 4.60 | 1.4 | 1.2 | .3 | 7.5 |
| Embraer EMB-120 | 23.80 | 8.7 | 18.3 | 2.4 | 53.3 |
| Fokker F27 | 684.40 | 15.6 | 23.3 | .0 | 723.3 |
| Fokker F28 | 285.50 | .0 | 196.3 | 17.8 | 499.6 |
| Lockheed L-1011 | 25.00 | 1.0 | 2.0 | 1.0 | 29.1 |
| Lockheed L188 | 188.10 | 3.0 | 3.0 | 6.0 | 200.0 |
| National Aircraft Manufacturing YS-11 | 632.90 | .0 | 126.6 | .0 | 759.5 |
| Saab 340 | 19.20 | 5.6 | 17.0 | 3.6 | 45.4 |
| Shorts 330 | 545.50 | 909.1 | 727.3 | 181.8 | 2,363.6 |

Note: Airplane events are categorized by the following hazard levels — Level 1 (no effect) for no effect on the operation of the airplane; Level 2 (minor) for little effect on crew and/or passengers; Level 3 (major) for major event with significant workload increase for pilots and/or expert actions required for resolution; Level 4 (hazardous) for damage to airplane and/or occupants injured; and, Level 5 (catastrophic) for airplane destroyed as a result of event(s) and/or multiple fatalities. The database contained no Level 5 events.

Source: Flight Safety Foundation Continuing Airworthiness Risk Evaluation (CARE) Study Team

# Appendix B

# U.S. Federal Aviation Regulations Airworthiness Reporting Requirements

## § 121.703 Mechanical reliability reports

(a) Each certificate holder shall report the occurrence or detection of each failure, malfunction, or defect concerning —

- (1) Fires during flight and whether the related fire warning system functioned properly;
- (2) Fires during flight not protected by a related fire warning system;
- (3) False fire warning during flight;
- (4) An engine exhaust system that causes damage during flight to the engine, adjacent structure, equipment, or components;
- (5) An aircraft component that causes accumulation or circulation of smoke, vapor, or toxic or noxious fumes in the crew compartment or passenger cabin during flight;
- (6) Engine shutdown during flight because of flameout;
- (7) Engine shutdown during flight when external damage to the engine or airplane structure occurs;
- (8) Engine shutdown during flight due to foreign object ingestion or icing;
- (9) Engine shutdown during flight of more than one engine;
- (10) A propeller feathering system or ability of the system to control overspeed during flight;
- (11) A fuel or fuel dumping system that affects fuel flow or causes hazardous leakage during flight;
- (12) An unwanted landing gear extension or retraction, or an unwanted opening or closing of landing gear doors during flight;
- (13) Brake system components that result in loss of brake actuating force when the airplane is in motion on the ground;
- (14) Aircraft structure that requires major repair;
- (15) Cracks, permanent deformation, or corrosion of aircraft structures, if more than the maximum acceptable to the manufacturer or the FAA (U.S. Federal Aviation Administration);
- (16) Aircraft components or systems that result in taking emergency actions during flight (except action to shut down an engine); and
- (17) Emergency evacuation systems or components including all exit doors, passenger emergency evacuation lighting systems, or evacuation equipment that are found defective, or that fail to perform the intended functions during an actual emergency or during training, testing, maintenance, demonstrations, or inadvertent deployments.

(b) For the purpose of this section "during flight" means the period from the moment the aircraft leaves the surface of the earth on takeoff until it touches down on landing.

(c) In addition to the reports required by paragraph (a) of this section, each certificate holder shall report any other failure, malfunction, or defect in an aircraft that occurs or is detected at any time if, in its opinion, that failure, malfunction, or defect has endangered or may endanger the safe operation of an aircraft used by it.

(d) Each certificate holder shall send each report required by this section, in writing, covering each 24 hour period beginning at 0900 local time of each day and ending at 0900 local time on the next day, to the certificate-holding district office. Each report of occurrences during a 24 hour period must be mailed or delivered to that office within the next 72 hours. However, a report that is due on Saturday or Sunday may be mailed or delivered on the following Monday, and one that is due on a holiday may be mailed or delivered on the next work day.

(e) The certificate holder shall transmit the reports required by this section in a manner and on a form that is convenient to its system of communication and procedure, and shall include in the first daily report as much of the following as is available:

- (1) Type and identification number of the aircraft.
- (2) The name of the operator.
- (3) The date, flight number, and stage during which the incident occurred (e.g., preflight, takeoff, climb, cruise, descent, landing, and inspection).
- (4) The emergency procedure effected (e.g., unscheduled landing and emergency descent).
- (5) The nature of the failure, malfunction, or defect.

(6) Identification of the part and system involved, including available information pertaining to type designation of the major component and time since overhaul.

(7) Apparent cause of the failure, malfunction, or defect (e.g., wear, crack, design deficiency, or personnel error).

(8) Whether the part was repaired, replaced, sent to the manufacturer, or other action taken.

(9) Whether the aircraft was grounded.

(10) Other pertinent information necessary for more complete identification, determination of seriousness, or corrective action.

(f) A certificate holder that is also the holder of a Type Certificate (including a Supplemental Type Certificate), a Parts Manufacturer Approval, or a Technical Standard Order Authorization, or that is the licensee of a type certificate holder, need not report a failure, malfunction, or defect under this section if the failure, malfunction, or defect has been reported by it under § 21.3 of this chapter or under the accident reporting provisions of 14 CFR part 830 {Reference should be to 49 CFR part 830 — Ed.}.

(g) No person may withhold a report required by this section even though all information required in this section is not available.

(h) When certificate holder gets additional information, including information from the manufacturer or other agency, concerning a report required by this section, it shall expeditiously submit it as a supplement to the first report and reference the date and place of submission of the first report.

[Doc. No. 6258, 29 FR 19226, Dec. 31, 1964, as amended by Doc. No. 8084, 32 FR 5770, Apr. 11, 1967; Amdt. 121-72, 35 FR 18188, Nov. 28, 1970; Amdt. 121-143, 43 FR 22642, May 25, 1978; Amdt. 121-178, 47 FR 13316, Mar. 29, 1982; Amdt. 121-187, 50 FR 32375, Aug. 9, 1985; Amdt. 121-195, 53 FR 8728, Mar. 16, 1988; Amdt. 121-251, 60 FR 65936, Dec. 20, 1995]

### § 121.705 Mechanical interruption summary report

Each certificate holder shall regularly and promptly send a summary report on the following occurrences to the Administrator:

(a) Each interruption to a flight, unscheduled change of aircraft enroute, or unscheduled stop or diversion from a route, caused by known or suspected mechanical difficulties or malfunctions that are not required to be reported under § 121.703.

(b) The number of engines removed prematurely because of malfunction, failure or defect, listed by make and model and the aircraft type in which it was installed.

(c) The number of propeller featherings in flight, listed by type of propeller and engine and aircraft on which it was installed. Propeller featherings for training, demonstration, or flight check purposes need not be reported.

[Doc. No. 6258, 29 FR 19226, Dec. 31]

### § 135.415 Mechanical reliability reports

(a) Each certificate holder shall report the occurrence or detection of each failure, malfunction, or defect in an aircraft concerning —

(1) Fires during flight and whether the related fire warning system functioned properly;

(2) Fires during flight not protected by related fire warning system;

(3) False fire warning during flight;

(4) An exhaust system that causes damage during flight to the engine, adjacent structure, equipment, or components;

(5) An aircraft component that causes accumulation or circulation of smoke, vapor, or toxic or noxious fumes in the crew compartment or passenger cabin during flight;

(6) Engine shutdown during flight because of flameout;

(7) Engine shutdown during flight when external damage to the engine or aircraft structure occurs;

(8) Engine shutdown during flight due to foreign object ingestion or icing;

(9) Shutdown of more than one engine during flight;

(10) A propeller feathering system or ability of the system to control overspeed during flight;

(11) A fuel or fuel dumping system that affects fuel flow or causes hazardous leakage during flight;

(12) An unwanted landing gear extension or retraction or opening or closing of landing gear doors during flight;

(13) Brake system components that result in loss of brake actuating force when the aircraft is in motion on the ground;

(14) Aircraft structure that requires major repair;

(15) Cracks, permanent deformation, or corrosion of aircraft structures, if more than the maximum acceptable to the manufacturer or the FAA; and

(16) Aircraft components or systems that result in taking emergency actions during flight (except action to shut down an engine).

(b) For the purpose of this section, “during flight” means the period from the moment the aircraft leaves the surface of the earth on takeoff until it touches down on landing.

(c) In addition to the reports required by paragraph (a) of this section, each certificate holder shall report any other failure, malfunction, or defect in an aircraft that occurs or is detected at any time if, in its opinion, the failure, malfunction, or defect has endangered or may endanger the safe operation of the aircraft.

(d) Each certificate holder shall send each report required by this section, in writing, covering each 24 hour period beginning at 0900 hours local time of each day and ending at 0900 hours local time on the next day to the FAA Flight Standards District Office charged with the overall inspection of the certificate holder. Each report of occurrences during a 24 hour period must be mailed or delivered to that office within the next 72 hours. However, a report that is due on Saturday or Sunday may be mailed or delivered on the following Monday and one that is due on a holiday may be mailed or delivered on the next work day. For aircraft operated in areas where mail is not collected, reports may be mailed or delivered within 72 hours after the aircraft returns to a point where the mail is collected.

(e) The certificate holder shall transmit the reports required by this section on a form and in a manner prescribed by the Administrator, and shall include as much of the following as is available:

(1) The type and identification number of the aircraft.

(2) The name of the operator.

(3) The date.

(4) The nature of the failure, malfunction, or defect.

(5) Identification of the part and system involved, including available information pertaining to type designation of the major component and time since last overhaul, if known.

(6) Apparent cause of the failure, malfunction or defect (e.g., wear, crack, design deficiency, or personnel error).

(7) Other pertinent information necessary for more complete identification, determination of seriousness, or corrective action.

(f) A certificate holder that is also the holder of a type certificate (including a supplemental type certificate), a Parts Manufacturer Approval, or a Technical Standard Order Authorization, or that is the licensee of a type certificate need not report a failure, malfunction, or defect under this section if the failure, malfunction, or defect has been reported by it under § 21.3 or § 37.17 {There is no Part 37 — Ed.} of this chapter or under the accident reporting provisions of Part 830 of the regulations of the National Transportation Safety Board.

(g) No person may withhold a report required by this section even though all information required by this section is not available.

(h) When the certificate holder gets additional information, including information from the manufacturer or other agency, concerning a report required by this section, it shall expeditiously submit it as a supplement to the first report and reference the date and place of submission of the first report.

### § 135.417 Mechanical interruption summary report

Each certificate holder shall mail or deliver, before the end of the 10th day of the following month, a summary report of the following occurrences in multiengine aircraft for the preceding month to the certificate-holding district office:

(a) Each interruption to a flight, unscheduled change of aircraft enroute, or unscheduled stop or diversion from a route, caused by known or suspected mechanical difficulties or malfunctions that are not required to be reported under § 135.415.

(b) The number of propeller featherings in flight, listed by type of propeller and engine and aircraft on which it was installed. Propeller featherings for training, demonstration, or flight check purposes need not be reported.

[Amdt. 135-60, 61 FR 2616, Jan. 26, 1996]

### § 135.419 Approved aircraft inspection program

(a) Whenever the Administrator finds that the aircraft inspections required or allowed under Part 91 of this chapter are not adequate to meet this part, or upon application by a certificate holder, the Administrator may amend the certificate holder's operations specifications under § 135.17, to require or allow an approved aircraft inspection program for any make and model aircraft of which the certificate holder has the exclusive use of at least one aircraft (as defined in § 135.25(b)).

(b) A certificate holder who applies for an amendment of its operations specifications to allow an approved aircraft inspection program must submit that program with its application for approval by the Administrator.

(c) Each certificate holder who is required by its operations specifications to have an approved aircraft inspection program shall submit a program for approval by the Administrator within 30 days of the amendment of its operations specifications or within any other period that the Administrator may prescribe in the operations specifications.

(d) The aircraft inspection program submitted for approval by the Administrator must contain the following:

  (1) Instructions and procedures for the conduct of aircraft inspections (which must include necessary tests and checks), setting forth in detail the parts and areas of the airframe, engines, propellers, rotors, and appliances, including emergency equipment, that must be inspected.

  (2) A schedule for the performance of the aircraft inspections under paragraph (d)(1) of this section expressed in terms of the time in service, calendar time, number of system operations, or any combination of these.

  (3) Instructions and procedures for recording discrepancies found during inspections and correction or deferral of discrepancies including form and disposition of records.

(e) After approval, the certificate holder shall include the approved aircraft inspection program in the manual required by § 135.21.

(f) Whenever the Administrator finds that revisions to an approved aircraft inspection program are necessary for the continued adequacy of the program, the certificate holder shall, after notification by the Administrator, make any changes in the program found by the Administrator to be necessary. The certificate holder may petition the Administrator to reconsider the notice to make any changes in a program. The petition must be filed with the representatives of the Administrator assigned to it within 30 days after the certificate holder receives the notice. Except in the case of an emergency requiring immediate action in the interest of safety, the filing of the petition stays the notice pending a decision by the Administrator.

(g) Each certificate holder who has an approved aircraft inspection program shall have each aircraft that is subject to the program inspected in accordance with the program.

(h) The registration number of each aircraft that is subject to an approved aircraft inspection program must be included in the operations specifications of the certificate holder.

## § 125.409 Reports of defects or unairworthy conditions

(a) Each certificate holder shall report the occurrence or detection of each failure, malfunction, or defect, in a form and manner prescribed by the Administrator.

(b) The report must be made within 72 hours to the FAA Flight Standards district office in whose area the certificate holder has its principal operations base. The procedures to be used in complying with this section must be made a part of the manual procedures required by § 125.73(f).

## § 145.63 Reports of defects or unairworthy conditions

(a) Each certificated domestic repair station shall report to the Administrator within 72 hours after it discovers any serious defect in, or other recurring unairworthy condition of, an aircraft, powerplant, or propeller, or any component of any of them. The report shall be made on a form and in a manner prescribed by the Administrator, describing the defect or malfunction completely without withholding any pertinent information.

(b) In any case where the filing of a report under paragraph (a) of this section might prejudice the repair station, it shall refer the matter to the Administrator for a determination as to whether it must be reported. If the defect or malfunction could result in an imminent hazard to flight, the repair station shall use the most expeditious method it can to inform the Administrator.

(c) The holder of a domestic repair station certificate that is also the holder of a part 121, 127 {Part 127 was removed at Amdt. 127-45, 60 FR 65832, Dec. 20, 1995 — Ed.}, or 135 certificate, a Type Certificate (including a Supplemental Type Certificate), a Parts Manufacturer Approval (PMA), or a TSO authorization, or that is the licensee of a Type Certificate, need not report a failure, malfunction, or defect under this section if the failure, malfunction, or defect has been reported by it, under

§ 21.3, § 37.17 {There is no Part 37 — Ed.}, § 121.703, § 127.313 {Part 127 was removed at Amdt. 127-45, 60 FR 65832, Dec. 20, 1995 — Ed.}, or § 135.57 {There is no § 135.57 — Ed.} of this chapter.

### § 145.79 Records and reports

(a) Each certificated foreign repair station shall maintain such records, and make such reports, with respect to United States registered aircraft, as the Administrator finds necessary, including those prescribed in paragraphs (b) and (c) of this section.

(b) Each certificated foreign repair station shall keep a record of the maintenance and alteration it performs on United States registered aircraft, in enough detail to show the make, model, identification number, and serial number of the aircraft involved, and a description of the work. In a case of major repairs or major alterations, or both, it shall report on a form and in a manner prescribed by the Administrator, giving the original copy to the aircraft owner and sending a copy to the Administrator through the FAA office having jurisdiction over the station. However, if a major repair or alteration is made on a United States scheduled flag air carrier aircraft, the report may be made in the log or other record provided by the carrier for that purpose. Upon request, the station shall make all of its maintenance and alteration records available to the Administrator.

(c) Each certificated foreign repair station shall, within 72 hours after it discovers any serious defect in, or other recurring unairworthy condition of, any aircraft, powerplant, propeller, or any component of any of them, that it works on under this part, report that defect or unairworthy condition to the Administrator.

(d) The holder of a foreign repair station certificate that is also the holder of a Type Certificate (including a Supplemental Type Certificate), a Parts Manufacturer Approval (PMA), or a TSO authorization or that is the licensee of a Type Certificate need not report a failure, malfunction, or defect under this section if the failure, malfunction, or defect has been reported by it, under § 21.3 of this chapter or § 37.17 {There is no Part 37 — Ed.} of this chapter.♦

# Appendix C
# The Relationship of Reporting Requirements to Issuance of Airworthiness Directives — Joint Aviation Requirements

## JAR 21.3 and Associated Advisory Material

## JAR 21.3 Failures, malfunctions and defects

(a) System for Collection, Investigation and Analysis of Data. (See [Advisory Circular–Joint (ACJ)] 21.3(a).) The holder of a Type Certificate or Supplemental Type Certificate, shall have a system for collecting, investigating and analyzing information related to Occurrences that may involve failures, malfunctions or defects in any product, part or appliance covered by the Type Certificate or Supplemental Type Certificate. The holder of a Type Certificate or Supplemental Type Certificate for a product shall provide information about the system developed in accordance with this sub-paragraph (a) of this paragraph to each known operator of each product.

(b) Reporting to the Authority

(1) The holder of a Type Certificate, Supplemental Type Certificate, Joint Parts Approval (JPA) Authorization or Joint Technical Standards Order (JTSO) Authorization shall report to his National Authority any failure malfunction or defect in a product, part, or appliance covered by the Type Certificate, Supplemental Type Certificate or Authorization of which he is aware and which has resulted in or may result in an unsafe condition.

(2) Reports must be made in a form and manner acceptable to the Authority, as soon as practicable and in any case not later than three days after the identification of the failure, malfunction or defect by the holder of the Certificate, Approval or Authorization. (See ACJ 21.3(b)(2.)

(c) Investigation of Reportable Occurrences

Whenever the analysis made under sub-paragraph (a) of this paragraph shows that the reported Occurrence involves a failure, malfunction or defect arising from a deficiency in the Type Design, or a manufacturing deficiency, the Type Certificate holder, the Supplemental Type Certificate holder, the holder of a JTSO Authorization, or the holder of a JPA Authorization, as appropriate, shall investigate the reason for the deficiency and report to the Authority the results of his investigation and any action he is taking or proposes to take to correct that deficiency. If the Authority finds action is required to correct the deficiency in existing products, parts or appliances, the Type Certificate holder, the Supplemental Type Certificate holder, the holder of a JTSO Authorization, or the holder of a JPA Authorization, as appropriate, shall submit the necessary data relating to the corrective action to the Authority.

(d) Required Action — Design Change or Inspection

When the Authority considers that issuance of an Airworthiness Directive is necessary to correct the unsafe condition, or to require the performance of an inspection the holder of the Certificate, Approval or Authorization shall —

(1) Propose the appropriate design changes and/or required inspections and submit details of these proposals to the Authority for approval.

(2) Following the Authority's approval of the proposed design changes or inspections, make available to all known Operators appropriate descriptive data and accomplishment instructions.

### ACJ 21.3(a)
### The System for Collection, Investigation and Analysis of Data (Interpretative Material)
### See JAR 21.3(a)

In the context of this requirement the word "collect" means, the setting up, of systems and procedures which will enable relevant malfunctions, failures and defects to be properly reported when they occur.

### ACJ 21.3(b)(2)
### Reporting to the Authority
### (Acceptable Means of Compliance)
### See JAR 21.3(b)(2)

Within the overall limit of three days the degree of urgency for submission of a report should be determined by the level of hazard judged to have resulted from the occurrence.

Where an occurrence is judged by a reporter to have resulted in an immediate and particularly significant hazard the authority expects to be advised immediately and by fastest possible means (telephone, fax, telex) of whatever details are available at that time. This initial report to be followed up by a full written report within three days. A typical example would be an uncontained engine failure resulting in damage to aircraft primary structure.

Where the occurrence is judged to have resulted in a less immediate and less significant hazard, report submission may be delayed up to the maximum of three days in order to provide more details.

## JAR 39 Procedure Document for Issuance of Airworthiness Directives by JAA National Airworthiness Authorities

### Selected Material

### 2. Issuance of Airworthiness Directives for Products, Parts and Appliances by a JAA Authority as the Primary Airworthiness Authority

### 2.1 Corrective Action

After a determination of an unsafe condition is made, a corrective action must be proposed by the TC, STC or Approval holder and submitted to the PAA for approval.

The following should be considered by the PAA in evaluating the corrective action:

The corrective action may include:

- repair;
- removal from service;
- a design change;
- an inspection; and/or,
- a modification of the limitations or procedures associated with the product, part or appliance (AFM, life limits, Certification Maintenance Requirements … ).

| | | |
|---|---|---|
| Appendix 1 | JAA Airworthiness Directive form | 1 page |
| Appendix 2 | Changes to Previously Issued Airworthiness Directives | 5 pages |
| Appendix 3 | Risk Assessment | 5 pages |
| Appendix 4 | Guidelines for Writing Airworthiness Directives | 14 pages |

### JAR 39 ACJs

| | | |
|---|---|---|
| ACJ 1 | Identification of Responsible Authority | 1 page |
| ACJ 2 | Methodology for Determining When an Unsafe Condition Exists | 6 pages |
| ACJ 3 | Human Factors | 1 page |

## JAR–OPS 1.420 Occurrence Reporting
## JAR–OPS 1.425 Accident Reporting

### JAR–OPS 1.420 Occurrence Reporting

(a) Flight Incidents

(1) The operator or commander of an airplane shall submit a report to the Authority of any incident that has endangered or may have endangered safe operation of a flight.

(2) Reports shall be dispatched within 72 hours of the event, unless exceptional circumstances prevent this.

(b) Technical defects and exceedance of technical limitations. A commander shall ensure that all technical defects and exceedances of technical limitations occurring while he was responsible for the flight are recorded in the airplane's Technical Log.

(c) Air Traffic Incidents. A commander shall submit an air traffic incident report in accordance with ICAO PANS RAC whenever an airplane in flight has been endangered by:

(1) A near collision with any other flying device; or

(2) Faulty air traffic procedures or lack of compliance with applicable procedures by Air Traffic Services or by the flight crew; or

(3) A failure of ATS facilities.

(d) Bird Hazards and Strikes

(1) A commander shall immediately inform the appropriate ground station whenever a potential bird hazard is observed.

(2) A commander shall submit a written bird strike report after landing whenever an airplane for which he is responsible suffers a bird strike.

(e) In-flight emergencies with Dangerous Goods on board. If an in-flight emergency occurs and the situation permits, a commander shall inform the appropriate Air Traffic Services unit of any Dangerous Goods on board.

(f) Unlawful interference. Following an act of unlawful interference on board an airplane, a commander shall submit a report, as soon as practicable, to the local Authority and/or the Authority.

(g) Irregularities of ground and navigational facilities and hazardous conditions. A commander shall notify the appropriate ground station as soon as practicable whenever a potentially hazardous condition such as:

(1) An irregularity in a ground or navigational facility; or

(2) A meteorological phenomenon; or

(3) A volcanic ash cloud; or

(4) A high radiation level, is encountered during flight.

### JAR–OPS 1.425 Accident Reporting

(a) An operator shall establish procedures to ensure that the nearest appropriate authority is notified by the quickest available means of any accident, involving the airplane, resulting in serious injury (as defined in ICAO Annex 13) or death of any person or substantial damage to the airplane or property.

(b) A commander shall submit a report to the Authority of any accident on board, resulting in serious injury to, or death of, any person on board while he was responsible for the flight.♦

# New Zealand Reports Downward Trend In Accidents Involving Heaviest-category Aircraft

***Statistics compiled by the Civil Aviation Authority indicate that the accident rate also has declined for the heaviest category of aircraft. The most recent accidents in the two heaviest-weight categories of aircraft occurred in 1997.***

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*FSF Editorial Staff*

No aircraft accidents occurred in the two heaviest-weight categories of commercially operated passenger aircraft and cargo aircraft in New Zealand in 1998 and during the first three months of 1999 (Table 1, page 53), according to the New Zealand Civil Aviation Authority (CAA).

Data gathered by CAA show that one accident involving an airplane in the heaviest airplane category — commercial passenger airplanes and cargo airplanes weighing 13,608 kilograms (30,000 pounds) or more — occurred in 1997. The accident rate for airplanes in that category, calculated on a 10-year moving average (an average that is computed over a progressively shifting interval), is about 0.65 accidents for each 100,000 flight hours (Figure 1, page 53). The target rate set by CAA for 2000 is 0.5 accidents for each 100,000 flight hours, and the actual rate is "trending down slightly but is unlikely to meet the particularly demanding target," CAA said in its *Aviation Industry Safety Update,* which was revised in June 1999.

In the category comprising commercial passenger airplanes and cargo airplanes weighing from 5,670 kilograms (12,500 pounds) to 13,608 kilograms, the last accident occurred in 1997, and the accident rate on a 10-year moving average is about 0.9 for each 100,000 flight hours, slightly below the 2000 target rate of 1.0 accident per 100,000 flight hours (Figure 2, page 54).

For commercial passenger airplanes and cargo airplanes weighing 2,721 kilograms (6,000 pounds) to 5,670 kilograms, one accident occurred in 1998 and none occurred in the first three months of 1999. The accident rate, calculated on a five-year moving average, "increased progressively from late 1996 to halfway through 1997," CAA said. "It has now decreased to below the rate that existed in 1995, when the accident-reduction targets were set. However, the trend is still showing a significant divergence from the reduction target." The target is 2.0 accidents for each 100,000 flight hours; the current rate is about 6.0 accidents per 100,000 flight hours (Figure 3, page 54).

Other statistics compiled by CAA show:

- An accident rate for helicopters flown in commercial passenger operations and cargo operations, calculated

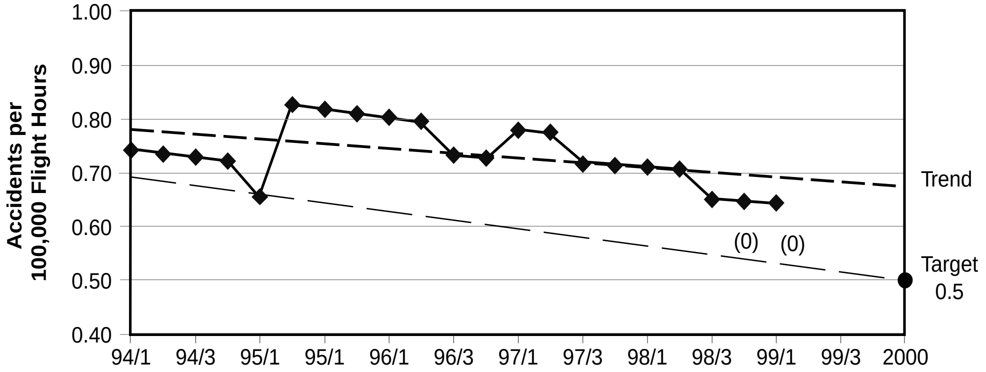
## Table 1
## Number of Accidents per Year Among Aircraft in New Zealand

| Aircraft Category | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 13,608 kg (30,000 lb.) and above revenue (passenger and freight) | 1 | 1 | 4 | 2 | 0 | 1 | 0 | 3 | 0 | 1 | 0 | 0 |
| 5,670 to 13,608 kg (12,500 to 30,000 lb.) revenue (passenger and freight) | 1 | 2 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 0 |
| 2,721 to 5,670 kg (6,000 to 12,500 lb.) revenue (passenger and freight) | 0 | 2 | 0 | 1 | 0 | 3 | 1 | 1 | 1 | 2 | 1 | 0 |
| Below 2,721 kg (6,000 lb.) revenue (passenger and freight) | – | – | – | – | – | – | 6 | 7 | 11 | 5 | 2 | 4 |
| Below 2,721 kg (6,000 lb.) revenue (other) | – | – | – | – | – | – | 20 | 24 | 17 | 13 | 17 | 3 |
| Below 2,721 kg (6,000 lb.) non-revenue | – | – | – | – | – | – | 39 | 22 | 21 | 20 | 21 | 8 |
| Helicopter revenue (passenger and freight) | – | – | – | – | – | – | 4 | 1 | 2 | 2 | 3 | 0 |
| Helicopter revenue (other) | – | – | – | – | – | – | 15 | 20 | 20 | 17 | 22 | 2 |

* First quarter of the year kg = Kilograms lb. = Pounds

Source: New Zealand Civil Aviation Authority

### 13,608 Kilograms (30,000 Pounds) and Above Commercial Passenger and Freight Accident Rate 10-year Moving Average

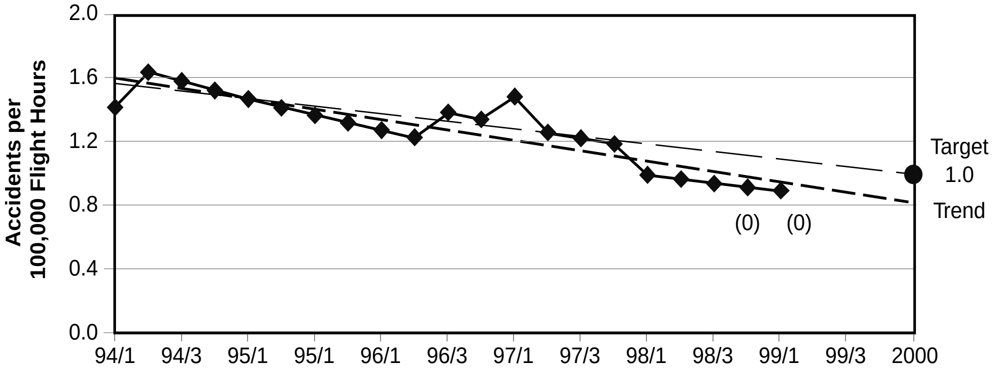


Source: New Zealand Civil Aviation Authority

Figure 1

on a 12-month moving average, of about 10.0 accidents for every 100,000 flight hours, compared with the 2000 target of 5.0 accidents per 100,000 flight hours.

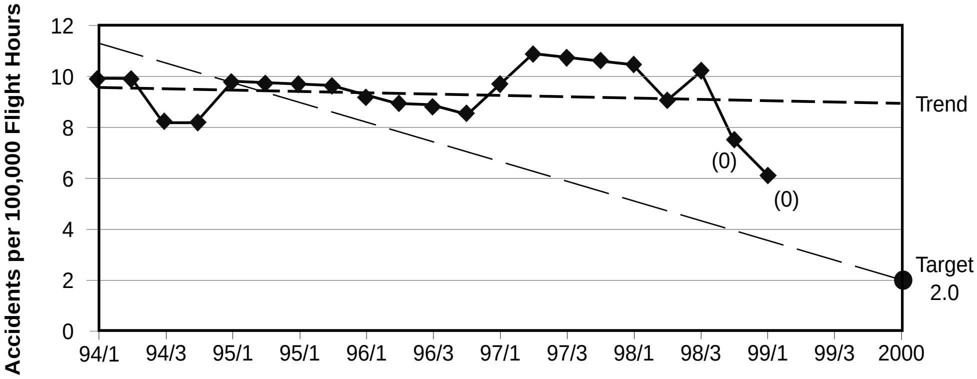
- An overall accident rate in 1998 of about 11.0 accidents per 100,000 flight hours.
- A fatal and serious injury rate of about 3.5 per 100,000 flight hours.
- Seventy-three registered aircraft weighing 13,608 kilograms or more as of March 31, 1999. The total number of registered aircraft was 3,330.
- About 10,500 licensed pilots as of March 31, 1999, including 1,437 pilots who held airline transport pilot licenses, 3,417 pilots who held commercial pilot licenses, 4,169 pilots who held private pilot licenses and 1,521 licensed flight engineers.♦



**5,670–13,608 Kilograms (12,500–30,000 Pounds) Commercial Passenger and Freight Accident Rate 10-year Moving Average**

Source: New Zealand Civil Aviation Authority

Figure 2



**2,721–5,670 Kilograms (6,000–12,500 Pounds) Commercial Passenger and Freight Accident Rate Five-year Moving Average**

Source: New Zealand Civil Aviation Authority

Figure 3

# Study Investigates Effects of Common Antihistamine on Pilot Performance

*Mixed results indicate negative effect of drug on some individuals.*

*FSF Library Staff*

## Reports

***Effects of Antihistamine, Age, and Gender on Task Performance.*** Gilliland, Kirby; Schlegel, Robert E.; Nesthus, Thomas E. U.S. Federal Aviation Administration (FAA) Office of Aviation Medicine. Report DOT/FAA/AM-99/20. July 1999. 72 pp. Available through NTIS.*

Keywords:
1. Antihistamines
2. Age
3. Gender
4. Cognitive Task Performance
5. Over-the-counter Medications

Over-the-counter drug use can compromise aviation worker effectiveness. Research has found an increase in the presence of over-the-counter drugs in aviation fatalities between 1988 and 1993. This study investigated the effects of chlorpheniramine maleate (a common over-the-counter antihistamine), age and gender on a range of performance tasks.

Participants consisted of 96 individuals made up of two groups of women (25–30 and 40–45 years of age), and three groups of men (25–30, 40–45, and 50–55 years of age).

Results provide some evidence that chlorpheniramine maleate has a negative effect on task performance in some individuals. Results also support the view that age is related to lower task performance. Gender appeared to influence performance, especially when combined with age. [Adapted from Introduction and Discussion.]

***Improving Pilot/ATC Voice Communication in General Aviation.*** Morrow, Daniel G.; Prinzo, O. Veronika. U.S. Federal Aviation Administration (FAA) Office of Aviation Medicine. Report DOT/FAA/AM-99/21. July 1999. 27 pp. Available through NTIS.*

Keywords:
1. General Aviation Communication
2. ATC Communication
3. Short-term Memory
4. Aging

Miscommunication between pilots and air traffic controllers is an infrequent but persistent problem in the National Airspace System. Complex air traffic control (ATC) messages sometimes overload a pilot's memory. This study investigated the influence of grouped versus sequential presentation of numerical information on general aviation pilot communication using a computer-controlled flight simulator.

Pilots were instructed to read back and follow ATC instructions. Read back errors and requests to clarify ATC messages were the primary measures of pilot communication.

As in earlier studies, longer ATC messages placed greater demands on pilot memory, and were more likely to cause communication problems. Pilots tended to translate grouped formats into the more familiar sequential format when reading back ATC messages. Only limited evidence was found that the grouped-instruction format improved pilot memory for ATC messages, except under demanding conditions. [Adapted from Introduction and Conclusions.]

***The Effects of Age and Practice on Aviation-Relevant Concurrent Task Performance.*** Milke, Ramon M.; Becker, James T.; Lambrou, Peter. U.S. Federal Aviation Administration (FAA) Office of Aviation Medicine. Report DOT/FAA/AM-99/22. August 1999. 16 pp. Available through NTIS.*

Keywords:
1. Aging and Performance
2. Learning
3. Multitasking
4. Neuropsychological Tests

Performance of cognitive tasks changes as individuals age. Recent studies have examined the relationship between aging, cognition and performance in pilots, emphasizing the importance of considering age effects on aviator skills. This study involved testing participants on five separate occasions over two days using a series of aviation-related neuropsychological tests.

Results showed that participants in the oldest group consistently performed slower and at a lower level than the youngest group, for all measures. Practice produced improvements in performance of all groups and for virtually all tasks. The data are consistent with previous studies examining participants based on age, and suggest that age-related factors should be considered during systems design and implementation. [Adapted from Introduction and Discussion.]♦

## Source

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## Updated U.S. Federal Aviation Administration (FAA) Regulations and Reference Materials

### Advisory Circulars (ACs)

| AC Number | Date | Title |
|---|---|---|
| 90-80B | April 12, 1999 | *Approval of Offshore Standard Approach Procedures, Airborne Radar Approaches, and Helicopter En Route Descent Areas* (cancels AC 90-80A, *Approval of Offshore Helicopter Approaches*, dated Oct. 21, 1988). |
| 140-2BB | June 16, 1999 | *FAA Certificated Pilot Schools Directory* (cancels AC 140-2AA, *List of Certificated Pilot Schools*, dated May 27, 1998). |
| 150/5210-7C | July 1, 1999 | *Aircraft Rescue and Fire-fighting Communications* (cancels AC 150/5210-7B, *Aircraft Fire and Rescue Communications*, dated April 30, 1984). |
| 183-32J | July 13, 1999 | *FAA Certificated Technical Personnel Examiners Directory* (cancels AC 183-32H, *FAA Designated Technical Personnel Examiners Directory*, dated Dec. 18, 1992). |

## International Reference Updates

### Joint Aviation Authorities

| Date | |
|---|---|
| Aug. 1, 1999 | JAR–OPS 3: Orange paper Amendment OPS 3/99/1 |
| Aug. 1, 1999 | JAR–145: Orange paper Amendment 145/99/1 |

### Airclaims

| Supplement Number | Date | |
|---|---|---|
| 115 | July 20, 1999 | Updates “Major Loss Record.” |

# Accident/Incident Briefs

# Retreaded Tire Explodes on Takeoff, Prompts Preparations for Postlanding Emergency

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

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*FSF Editorial Staff*

Air Carrier

## Investigators Call for New Ways To Check for Underinflation

*BAC 111 501EX. Minor damage. No injuries.*

Crewmembers heard a loud bang as the aircraft was rotated for takeoff from an airport in England. The aircraft handled normally, and there was no indication of any system problem. The pilots told air traffic control (ATC) about the event and requested a runway report while they continued their standard instrument departure and retracted the landing gear and the flaps with no apparent abnormalities.

ATC told the pilots that the crew on an arriving aircraft had reported rubber debris on the right side of the runway, and further examination of the runway confirmed that the debris was from a tire and that it was "extensive."

After flying the airplane to burn off excess fuel and briefing flight attendants and passengers on the possible need for an emergency evacuation after landing, the pilots returned to the airport for landing. They stopped the airplane on the runway with reverse thrust and gentle wheel braking, using minimal braking on the right wheels, and then shut down the engines. The outside tire on the right landing gear was damaged and smoking, but the crew decided that an emergency evacuation was not necessary. Subsequent examination found that the right inboard flap also received heavy damage from the impact, and the inside tire on the right landing gear received slight damage.

Records showed that the outside tire had been retreaded six times, and the incident occurred 296 landings after the sixth retreading. Evidence indicated that the outside tire "suffered premature failure as the result of excessive deflection, which could have been due to operating at some point while either underinflated or overloaded," the report said. "How such a condition could have occurred could not be established, as there was no record of significant underinflation having been found since the tires had been installed."

In its report on the incident, Britain's Air Accidents Investigation Branch asked the Civil Aviation Authority to consider requiring installation of a device to "provide ready indication" of hazardous levels of tire underinflation when underinflation cannot be detected by visual inspection of the wheels of an aircraft.

## Bounced Landing Results in Tail Strike

*Airbus A300-600R. Substantial damage. No injuries.*

After an uneventful flight, the crew was conducting a very-high-frequency omnidirectional radio approach to an airport in the Caribbean. At 2,500 feet, they maneuvered to avoid an aircraft that was sighted visually. On final approach to landing, the captain reduced power to above idle. The airplane was slightly above the planned descent angle at 1,000 feet, but by the time it descended to 500 feet, the crew considered it "in the slot" with airspeed about 20 knots higher than reference speed and decreasing.

The first officer said that at about 200 feet, he told the captain that the airspeed was low, and the captain responded by adding power. "The approach appeared normal until the automatic aural altitude callout began at 50 feet," the report said. "The captain sensed that the timing of the callouts from 30 feet down were slightly faster than normal."

The captain said that he flared the airplane at about 30 feet, reduced power to idle and "deepened" the landing flare just before touchdown, which was reported as "firm" and resulted in a bounced landing. A second touchdown occurred with the airplane in a higher than normal pitch attitude.

A flight attendant said that she heard "a loud noise" when the aircraft landed, and a postflight inspection revealed that a tail strike had occurred. The 170 passengers and crewmembers were not injured, but the aircraft received substantial damage.

## Air Taxi Commuter

## Pilot Cites Brake Failure In Runway Excursion

*Cessna 402C. Airplane destroyed. One serious injury; seven minor injuries.*

Visual meteorological conditions prevailed when the airplane began its landing roll at an airport in the Caribbean about 1700 hours local time. The pilot said that the brakes failed during the landing roll, and as the airplane approached the end of the runway, he steered it off the runway to the left to avoid the steep drop-off that was straight ahead. The report said the airplane collided with a ditch and was destroyed in a postaccident fire. One passenger suffered serious injuries; six passengers and the pilot received minor injuries.

## Accidental Use of Brake Linked to Landing Accident

*Fokker F27. No damage. One minor injury.*

Visibility was six kilometers (3.7 statute miles) and there were low clouds over the airport in England as the pilots flew an instrument landing system (ILS) approach. The first officer was the pilot flying, and the flight was part of his initial line training.

The crew reported a normal touchdown on the runway centerline. The aircraft slowed, and the captain reminded the first officer to use aileron and rudder to compensate for the crosswind component of 13 knots. After the captain noticed that the control wheel had returned to its neutral position, he took over the control column.

Soon afterward, the aircraft moved first to the right and then "swung violently to the left," the report said. Both pilots applied right rudder pressure, and the captain used the tiller to steer to the right. The aircraft moved from the pavement to the grass on the left side, then started to turn right, and came to a stop with the left main landing gear on the grass and the right landing gear and the nose gear back on the pavement.

No damage was found to the airplane, and subsequent examination revealed no problems with the landing gear, brakes, wheels or nosewheel steering system. The report said that possibly, when the first officer applied right rudder, he also inadvertently pressed the left brake pedal.

"Although the initial brake application may have been quite small, an increase in right rudder would have been needed to counteract it," the report said. "The situation would have progressed until full right rudder was applied with a large application of left brake."

## Ice Found on Aircraft After Hard Landing

*Cessna 208B. Substantial damage. No injuries.*

The aircraft was cruising at 4,000 feet when the pilot noticed the formation of moderate ice. The pilot asked air traffic control to approve a climb to a higher altitude, and after the request was granted, the pilot climbed to 6,700 feet. The aircraft would climb no higher, and the pilot then maintained 6,500 feet until beginning a very-high-frequency omnidirectional radio distance-measuring equipment approach to an airport in the United States.

When the airplane was over the runway, the pilot reduced power, and the airplane began to descend rapidly, the report said. The pilot then added power but the excessive sink rate continued, and the airplane touched down hard and veered off the left side of the runway. About 1 1/2 inches (38 millimeters) of clear ice was seen on the wings' leading edges and the empennage.

**Corporate Business**

## Preflight Inspection Fails to Identify Incorrect Aileron Connections

*Beech 1900C. Substantial damage. No injuries.*

The pilot conducted a preflight inspection before a maintenance flight check of the airplane, which had been out of service for refurbishing. His inspection included a check of the flight controls during which he noticed no incorrect movement of the ailerons.

As the airplane was rotated for takeoff at an airport in the United States, the left wing dropped. The pilot applied right aileron, but the left wing remained low. The airplane struck the left edge of the runway and the left wing hit a taxi sign. An examination of the aircraft revealed that the aileron control cables had been connected incorrectly at the turnbuckles in the wheel well.

## Engine Failure During Takeoff Prompts Forced Landing

*Piper PA-32-260. Airplane destroyed. Five fatalities.*

Visual meteorological conditions prevailed for the midmorning takeoff from an airport in Ecuador. A witness on the ground heard the engine speed fluctuate during the aircraft's initial climb, and other witnesses said that they saw the airplane gliding, with its propeller stopped, as the pilot maneuvered around buildings and populated areas. The airplane collided with a telephone pole before striking the ground in an outdoor basketball court. The impact and the resulting fire destroyed the airplane; the pilot and four passengers were killed.

## Emergency Landing Follows In-flight Attempt to Restart Engine

*Piper PA-32-300. Substantial damage. One minor injury.*

Visual meteorological conditions prevailed for the last segment of a three-segment flight to an airport in the United States. The commercial pilot, who was the airplane's only occupant, said that he was descending from 8,500 feet and had reached about 3,500 feet when the engine quit without warning. The pilot said that the left main fuel tank was empty, and he had been operating from the right main fuel tank. Wing-tip fuel tanks on both the left wing and right wing were full, he said, and he alternated between them as he made several unsuccessful attempts to restart the engine.

The pilot then selected an emergency landing area in a small clearing among trees. During the landing, the airplane struck several small trees, then touched down in a boggy area. The wings, empennage, landing gear and fuselage were damaged.

**Other General Aviation**

## Competitor's Wake Suspected In Racing Airplane Accident

*Cassutt Speed One. Airplane destroyed. One serious injury.*

Visual meteorological conditions and an easterly wind of 10 knots prevailed during the race at an airport in England in which the airplane was participating. The racecourse was an oval that included the active runway; the length of the course was about 4 kilometers (2.5 miles).

The pilot said that the race had proceeded without incident, but then, as he approached the finish line at an altitude of about 100 feet above ground level, he began to pass a slower aircraft. "At this point, the pilot experienced a violent force, accompanied by a sudden rearward movement of the control column, which was snatched from his hand," the report said. "The aircraft then entered a divergent pitch oscillation for about four cycles before it struck the runway and disintegrated."

The pilot, who suffered serious burns on his right hand, said that the accident probably was a result of flying through the other aircraft's wake.

## Contaminated Fuel Cited in Engine Failure

*Champion 7ECA. Substantial damage. No injuries.*

The pilot of a banner-towing operation flew for 2.5 hours, then stopped to refuel the aircraft at an airport in the United States. After refueling, the pilot took off and flew to an altitude of about 250 feet. The engine lost power, and the pilot returned to the airport for an emergency landing. The aircraft overran the runway and struck a building.

The aircraft had been fueled from a 55-gallon (208-liter) drum, and immediately after refueling, the pilot had taken fuel samples from the aircraft's tanks. An inspector from the U.S. Federal Aviation Administration later took fuel samples from the gascolator and carburetor, and found that both contained large amounts of water.

## Airplane Crippled by Unnoticed Tow Bar

*Falco F8L. Minor damage. No injuries.*

The pilot conducted a preflight inspection in a hangar at an airport in Scotland, and then his passenger pulled the aircraft out of the hangar using a tow bar attached to the nosewheel. The pilot completed some paperwork and asked the passenger to remove the tow bar. Then the pilot and his passenger boarded the aircraft, and the pilot taxied to the runway.

An air traffic controller told the pilot by radio that the tow bar was still attached to the aircraft's nosewheel. The pilot acknowledged the message by radioing back his aircraft's call sign as he continued taxiing toward the runway. "On entering the runway, the nose landing gear folded back," the report said.

The tow bar probably got caught on the raised lip of the runway, the report said. The passenger had not heard the pilot's instructions to remove the tow bar. Later, the pilot listened to a recording of relevant transmissions from the controller and acknowledged that there had been a transmission about the tow bar but that it was unintelligible. The pilot said that he should have asked the controller to repeat the message. The pilot also "observed that all preflight checks should be completed by the captain immediately before boarding the aircraft."

## Rotorcraft

## Engine Problem Prompts Emergency Landing

*Bell 205A-1. Substantial damage. One serious injury.*

Visual meteorological conditions prevailed when the pilots landed the helicopter on a dirt road in the United States so that they could switch seats during a night training flight. After a crew briefing, the pilot flying lifted off and began a climb to the north. Ten seconds to 15 seconds later, when the helicopter reached an altitude of about 75 feet, the pilot began a turn to the west. Almost immediately, there was a loud clunking sound, accompanied by vibrations. "The engine then emitted a loud, grinding, metallic grating sound," the report said. "Simultaneously, warning lights, engine chip lights, and the [revolutions per minute] decay light illuminated."

The pilot lowered the collective and entered autorotation. Because the helicopter was too low and its airspeed was too slow to return to the dirt road, the pilot began a 180-degree turn down a canyon. He performed a flare and a near-vertical descent, and the helicopter landed hard.

An examination of the aircraft revealed no smoke and no leaking fuel. The pilot said that the engine and rotors were stopped and that he had no difficulties operating the helicopter before the engine problem. The helicopter was substantially damaged in the hard landing. One crewmember suffered serious injuries; the pilot and another crewmember were not injured.

## Tail Rotor Damaged in Encounter with Wind Sock

*Bell 206L-3. Substantial damage. No injuries.*

The pilot was positioning the aircraft to land on an oil platform in visual meteorological conditions with a 10-knot wind when he heard "a buzzing sound followed by a right yaw." He then executed a hovering autorotation. The pilot suspected that the tail rotor had come in contact with the wind sock during the approach, and examination of the wind sock's internal frame revealed evidence of a tail-rotor blade strike, the report said.

Maintenance workers later found about four inches missing from the tip of one of the tail-rotor blades. In addition, the tail-rotor gearbox was torn from its mounting, and the tail boom sustained structural damage. The pilot, who was the helicopter's only occupant, was not injured in the incident.

## Gusty Winds End Flying Lesson

*Schweizer 269C-1. Substantial damage. Two minor injuries.*

The student pilot had completed three circuits at an airport in England when the instructor decided to end the lesson because of wind gusts that were estimated between 20 knots and 30 knots.

The instructor took control of the helicopter, intending to fly it across the runway and back to the landing pad, the report said. As the helicopter climbed through 20 feet during a towering takeoff, the instructor realized that he was overpitching and that the engine revolutions per minute (rpm) were decreasing. He reduced collective pitch in an attempt to increase rpm and immediately experienced a high sink rate. He then increased collective pitch but could not stop the helicopter from striking the ground hard.

The helicopter rolled to the right and came to rest on its right side. The aircraft was substantially damaged, and the instructor and the student pilot suffered minor injuries.♦

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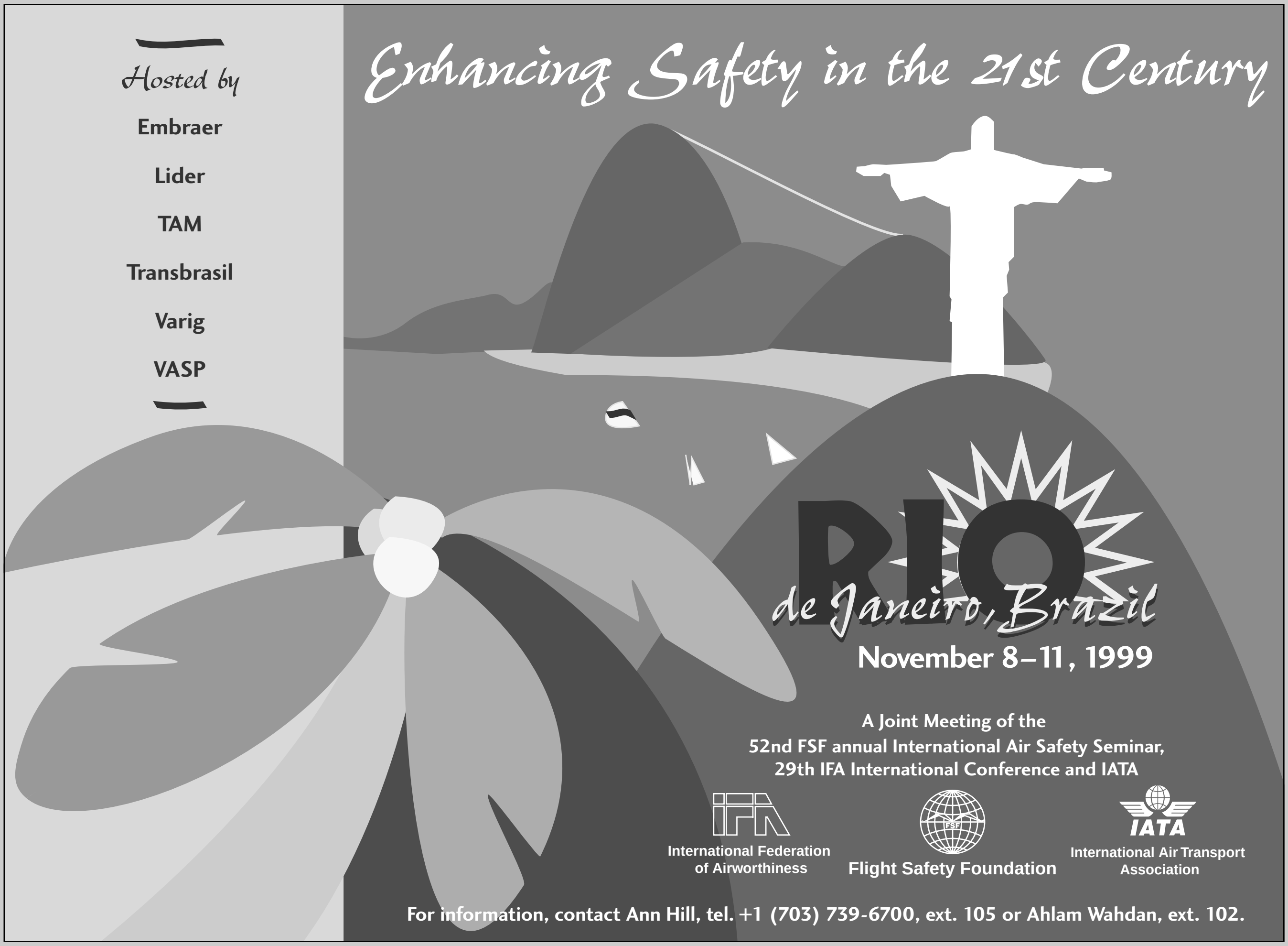

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