Chapter 4

Safety Measurements and Data Resources

Photo credit: Federal *Aviation Administration*

Air Safety databases are maintained at FAA's computer center in Oklahoma.

CONTENTS

Box

Figure

Tables

Safety Measurements and Data Resources

Transportation accidents account for only 2 percent of all deaths from any cause in the United States annually, and the public readily accepts the existence of travel risk. However, public concern varies for different kinds of risk, and intense attention focuses on air transportation, even though the fatality rate is very low. One reason maybe the relative perceptions of being in control of one's destiny—the operator of an automobile feels responsible for his own fate; the passenger on board a public conveyance does not. Nonetheless, more people die in private automobile accidents in an average month in the United States than have died in commercial aircraft accidents during the past 10 years.

A commercial aircraft crash, though a relatively rare event, can result in the simultaneous deaths of hundreds of people and often receives immense public attention, while a similar number of isolated fatalities is hardly noticed. The perceived loss to society is said to be proportional to the square of the number of people killed in a single incident, implying that 10,000 individual deaths are the same as 100 at once, and that public preventive efforts should follow accordingly.[1]

While sometimes irrational about safety, societies do attempt to minimize risk to the extent feasible and at an acceptable cost. Jimmy Doolittle expressed this well in a report in 1952 to President Truman:[2]

> The 'Calculated Risk' is an American concept which gives mobility to the whole structure. The phrase simply means a willingness to embark deliberately on a course of action which offers prospective rewards outweighing its estimated dangers. The American public accepts the calculated risk of transportation accidents as an inescapable condition to the enjoyment of life in a mechanical age. However, the public expects and cooperates to . . . narrow the gap between relative and absolute safety.

To know if risk is being reduced, one must be able to measure it, and the first half of this chapter outlines a theoretical framework for nonaccident safety data analysis. Collecting and analyzing many of these data may not be practical or feasible, however, and the discussion is presented as a guide to current safety data systems and their capabilities. The last sections of the chapter present analyses of existing safety databases and assess their utility and limitations.

I Albert L. Nichols and Richard J. Zechhauser, "The Perils of Prudence: How Conservative Risk Assessments Distort Regulation," *Regulation*, November/December 1986, pp. 13-24.

'Jerome Lederer, "Aviation Safety Perspectives: Hindsight, Insight, Foresight," *Nineteenth Wings Club 'Sight' Lecture*, presented at the Wings Club, New York City, Apr. 21, 1982, p. 3.

MEASURING TRANSPORTATION SAFETY

Safety Factors

In passenger transportation, safety factors are events or procedures that are associated with or influence fatality rates. The probability of death (or injury) as a result of traveling on a given mode, if it can be quantified, is the primary benchmark of passenger transportation safety. To be useful, alternative safety indicators must ultimately be correlated to this benchmark. Vehicle accident rates are also commonly used as safety indicators, since most passenger fatalities occur as a result of vehicle accidents.

If risk is defined as the probability of death, past risk in travling can be empirically determined from fatality rates. Commercial aviation accidents involving large jets can result in the deaths of hundreds of people; thus, a single accident can significantly influence fatality rates. Consequently, trend analyses of fatality rates require data from time periods of roughly 5 years or more, and these rates give poor indications of short-term changes in risk.

Accident rates can be an alternative to fatality rates as indicators of safety levels. While fatalities are often associated with aviation accidents, the number of fatalities, even for a specific type of accident, fluctuates considerably with each crash. The number of accidents may have a smaller range of yearly variance than the number of fatalities, but

Photo credit: National Transportation Safety Board

Major accidents result in tragic losses. Fortunately, such catastrophes are rare.

poses similar analysis problems. For example, midair collisions involving large, commercial jets have occurred twice in the United States during the last 10 years—little can be inferred from these numbers regarding changes in collision risk. Since the number of accidents is small and can vary significantly from one year to the next, accident rates are also poor indicators of short-term changes in risk.

Safety factors other than fatalities or accidents should be considered for prompt feedback on policy decisions or changes in the aviation operating environment. The Federal Government and the aviation industry maintain a wide assortment of safety-related information. However, without consideration of the accuracy, completeness, and original purpose of these databases, safety trend analyses based on this information are meaningless.

Exposure Data

Understanding the measures that are the denominators of transportation accident or fatality rates is necessary for safety analysis. The choice of which exposure data type to use affects how the rates can be compared across and within the transportation modes. Passenger-miles (the number of passengers multiplied by the miles traveled) are the best available exposure parameters for comparing air transportation with other modes and allow broad system comparisons.[3] Risk per passenger-mile is not uniform over a trip, and may vary by routing or

[3]Trips between specific city pairs would be a better measure, since the relative risks among different modes of travel between two points is the primary safety concern. However, the total number of city pairs in the United States is too large for comparative analysis and passenger data in this form are not readily available for some modes.

time of day. For example, the probability of an accident is significantly higher during takeoff or landing than while flying enroute; thus, most commercial aviation passenger-miles occur during much lower than overall average risk conditions. (For further information, see chapter 5.)

Since the number of passengers per vehicle can vary, vehicle-miles are often used to show exposure when comparing accident rates. Risk may not be uniform over each vehicle-mile traveled, and vehicle size and speed do not affect accident risk exposure indicated by vehicle-miles.

An aviation accident fatal to one passenger is likely to be fatal to many on board.[4] Since most of the risk involved with air transportation is associated with takeoff and landing, a 2,000-mile trip is similar to a 200-mile trip when compared for safety. Therefore, the number of trips (departures) is a valid exposure parameter for air transportation, and both passenger-departures (or -enplanements) and aircraft-departures can be used.

Finally, time is a common measure of exposure in many types of risk analyses. Flight-hour data are necessary for economic, operational, and maintenance requirements of aircraft and airlines. Since accurate data are kept, they are readily available as exposure information.

No single measurement provides the complete safety picture (see table 4-1). Passenger exposure data are used when passenger risk is to be indicated, while miles are used when it is important that the exposure data not be influenced by vehicle size or speed. Departure exposure data account for non-uniform risk over a trip. Time is a generic exposure measure in many fields, and data in that form are often readily available.

[4]On average, 50 percent of the passengers on board aircraft involved in fatal accidents perish. (See chs. 5 and 7.)

Nonaccident Safety Data

Accident investigations often uncover pervasive, but unrecognized, causal factors and can help prevent similar accidents from occurring. However, since commercial aviation accidents are so rare, other measures are needed for identifying short-term changes in safety. The goal of nonaccident data analysis is to help prevent the first accident from happening.

Potential safety indicators are measurable factors associated with or causally related to accidents, fatalities, or injuries. Ideally, the amount of data available will be large enough, unlike accident or fatality data, so that random events will have a small effect on yearly trends. The diagram of aviation accident causal and preventive factors (see figure 4-1) identifies sources for some nonaccident safety indicators.

In the diagram, items closely associated with accidents appear near the "accident" box. These offer the greatest potential as safety indicators and are explained in the following sections. Factors more removed from "accidents" have a correspondingly long causal link to them. These factors are measured against more subjective standards and may be more difficult to quantify -''industry policy, " for example.

Measurement Methodology

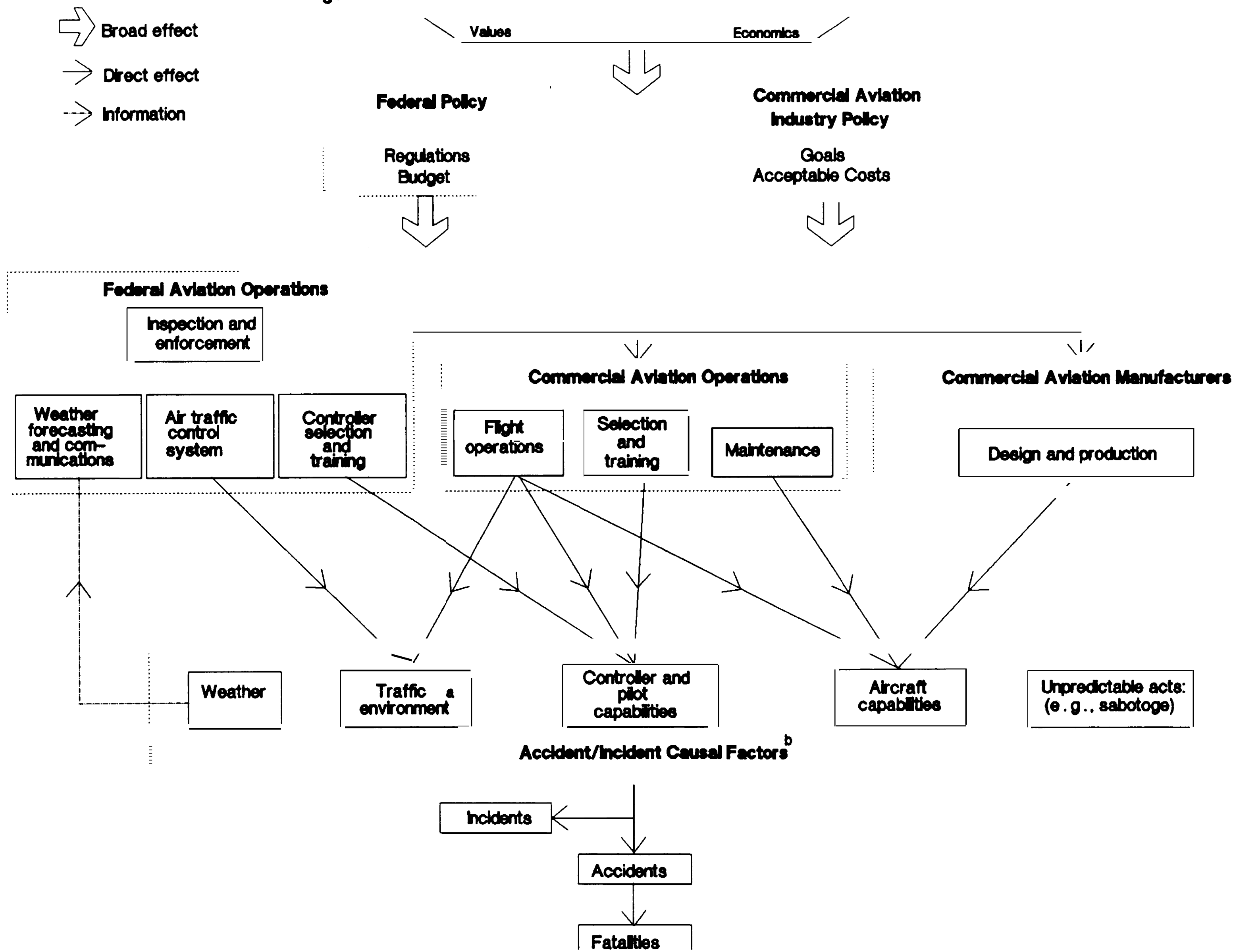
Clear and precise definitions exist for aviation accidents (see box 4-A); the consistent and accurate accident databases pose no problems for analysis from a measurement standpoint. Moreover, in the United States, every commercial aviation accident is tracked by the National Transportation Safety Board (NTSB), providing a complete set of aviation accident and fatality data. However, other indicators require consideration of the measurement meth-

Table 4.1 .—Safety Measures and Exposure Parameters

Critical events	Exposure parameters	
Injuries	Passenger-miles	Vehicle-miles
Fatalities	Passenger-hours	Vehicle-hours
Accidents	Passenger-departures (or -enplanements)	Vehicle-departures (or -trips)
Fatal accidents		

SOURCE: Office of Technology Assessment, 1988.

Figure 4-1.—Commercial Aviation Accident Causal and Preventive Factors



[a]Including general aviation, military, and other

[b]Causal factors influence each other.

SOURCE: Office of Technology Assessment.

Box 4-A.—Measures of Transportation Safety: Definitions

The context for these definitions is commercial aviation passenger transportation.

Accident: An occurrence associated with the operation of an aircraft which takes place between the time any person boards the aircraft with the intention of flight and all such persons have disembarked, and in which any person (occupant or non-occupant) suffers a fatal or serious injury or the aircraft receives substantial damage. (49 CFR 830.2)

Fatal Injury: Any injury which results in death within 30 days of the accident.

Serious Injury: Any injury which requires hospitalization for more than 48 hours, results in a bone fracture, or involves internal organs or burns.

Substantial Damage: Damage or failure which adversely affects the structural strength, performance, or flight characteristics of the aircraft, and which would normally require major repair or replacement of the affected component.

Incident: An occurrence other than an accident associated with the operation of an aircraft which affects or could affect the safety of operations. (49 CFR 830.2)

Level of Safety (or Risk): Fatality or injury rates. Only past levels of safety can be determined positively. Accident rates are closely associated with fatalities and injuries, and are acceptable measures of safety levels. Fatality, injury, and accident rates are benchmark safety indicators. Current and future safety levels must be estimated by other indicators or by extrapolating past trends.

Safety Factor: A procedure or event associated with fatalities, injuries, or accidents or their prevention.

Safety Indicator: A measurable safety factor.

Primary, Secondary, and Tertiary Safety Factors and Indicators: These safety factors and indicators describe the relative "closeness" between the measured safety factors and the fatality, injury, and accident rates. Theoretically, primary indicators would provide the best measures of changes in safety, followed by secondary and tertiary indicators. In practice, some tertiary indicators are more readily available and more accurate than primary indicators.

Primary Factors: These are most closely associated with fatalities, injuries, and accidents. Accident/incident causal factors, such as personnel and aircraft capabilities and the air traffic environment, are examples. Incidents and measurable primary factors are primary indicators.

Secondary Factors: These influence the primary factors. Airline operating, maintenance, personnel practices, along with Federal air traffic control management practices, are examples. Quantifiable measures of these factors, such as aircraft or employee utilization rates, are secondary indicators.

Tertiary Factors: These include Federal regulatory policy and individual airline corporate policy and capabilities that influence the secondary factors. An example of a tertiary indicator would be results of Federal air carrier inspections that quantify the extent of the carrier's regulatory compliance.

Exposure Data: Information that indicates the amount of opportunity for an event to occur. Cycles, distance, and time, for passengers or vehicles, are the principal exposure types. They are used in the denominator of rates, such as fatalities per passenger-departure and electrical system failures per aircraft-hour.

odology, because subjective influences and incomplete data affect analyses.

While most of the potential nonaccident indicators discussed in this section can be extracted from Federal and industry databases, in practice, they are not very useful for safety analysis. Much of the data come from voluntary reports submitted by pilots, mechanics, or controllers. Despite safety reporting requirements, ensuring compliance or consistency is difficult. Additionally, many of the databases were designed for administrative support functions, not as safety analysis tools.

Primary Safety Factors

Primary safety factors are those most closely correlated with accidents, and include incidents and accident causal factors. Theoretically, they are the best substitutes or alternatives to accident data.

Incidents

Incidents are events that can be defined loosely as "near-accidents."[5] Causal factors leading to accidents also lead to incidents, and all accidents begin as near accidents. The various combinations of possibly unsafe acts and conditions that occur each day usually end as incidents rather than accidents, and the larger number of incidents offers wider opportunities for safety trend analyses and for suggesting potential accident prevention measures. However, for an aviation incident to be widely known, it must be reported by at least one of the people involved. Yet, the definition of an incident is subject to the interpretation of the observer, and what appears to be an incident to one person may not to another. Thus, some information may be lost and measurement error may occur. Similar errors will result from incidents that are recognized, but not reported. Various sampling techniques can be employed for testing database consistency, and valid trend analyses are possible if errors in the data can be estimated. Incident types include:

Near Midair Collision (NMAC).-An incident associated with the operation of an aircraft in which the possibility of collision occurs as a result of proximity of less than 500 feet to another aircraft, or an official report is received from an aircrew member stating that a collision hazard existed between two or more aircraft.

Runway Incursion.–An occurrence at an airport involving an aircraft, vehicle, person, or object on the ground that creates a collision hazard or results in loss of separation with an aircraft taking off, intending to take off, landing, or intending to land.

In-flight Fire.–A fire that occurs aboard an aircraft, whether or not damage occurs. Fire is extremely dangerous to aircraft and passengers because of the confined nature of cockpits and cabins, the amount and flammability of fuel, and the time involved in landing and evacuating an aircraft. Flight crews are required to report occurrences of in-flight fires to NTSB.

[5]The National Transportation Safety Board considers an incident to be ". . . an occurrence other than an accident, associated with the operation of an aircraft, which affects or could affect the safety of operations." 49 CFR 830.2 (Oct. 1, 1987).

Flight-critical Equipment Failure.—''Flight-critical" is subject to various interpretations. Some examples are control system malfunctions and engine failures.

Accident Causal Factors

Aviation accident investigations attempt to determine and understand the causes leading to accidents, in the hope of preventing future mishaps. The findings can be grouped into five broad categories, as shown in the causal factors diagram. Few accidents (or incidents) result from a single, isolated cause—a combination of factors is usually involved. An examination of these causal factors points to possible indicators for monitoring safety levels. The five primary causal factor categories are discussed below.

Personnel Capabilities.–Human errors are factors in over two-thirds of commercial aviation accidents; they include lapses in attention, judgment, or perception and deficiencies in knowledge or motor skills. Such errors may be caused by vehicle, environmental, or health factors, including cockpit layout, workload, fatigue, or stress. Aviation personnel most subject to these errors include flight crewmembers, dispatchers, mechanics, and air traffic controllers.

In the operating environment, human errors are difficult to identify for a variety of reasons, including privacy and sensitivity; for example, possible measurements could include the results of periodic or continuous monitoring of operating personnel. However, human errors need to be understood to be prevented. Some indicators of personnel capabilities which are presently measured and used in either Federal or industry standards include employee duty hours, work hours, age, training, and experience levels.

Traffic Environment.–The structure of the airways and airports and the level and composition of air traffic heavily influence safety. Difficulties with facilities or traffic routing are usually discovered through incidents before an accident occurs. However, high traffic density puts continuous strains on many aspects of the air traffic control (ATC) system.

For a given air traffic infrastructure, increased traffic density most likely correlates with an increased risk of midair collisions. While the number of flight operations can be accurately counted or estimated, collisions occur too infrequently to correlate, and NMAC statistics are not as precise. Operational error, operational deviation, and pilot deviation statistics are also potential air traffic safety indicators, but have similar consistency problems. Controller workload, the ratio of operations to controllers, might provide insight on air traffic safety if the type of ATC equipment being used and the nature of the traffic mix are considered.

Aircraft Capabilities.—The failure of an aircraft component is a factor in over 40 percent of jetliner accidents. Examples of components include engines, structural members, landing gear, control systems, and instruments. Mechanical failures can result from improper maintenance, design flaws, or operator error.

Replacement or repair trends, especially for flight-critical components, are possible indicators of safety, although the severity, along with the frequency of the component failure must be considered in quantifying risk. The Federal Aviation Administration (FAA), air carriers, and aircraft manufacturers maintain detailed databases of mechanical reliability data. Analysis and communication of observed trends prevent most problems from becoming critical. Other broad indicators include engine shutdown rates and unscheduled landings due to mechanical difficulties.

Weather.—Modern aircraft can operate in virtually all kinds of weather, but unpredicted severe conditions, such as wind shear or heavy icing, can prove deadly. Poor weather, compounded by mechanical difficulties or errors in judgment, provides a common scenario for aviation accidents. An understanding and timely monitoring of weather conditions is required for safe operation of aircraft, as shown in figure 4-1.

Unpredictable Events.—These are factors not included in the above categories, such as sabotage or terrorism. By definition, unpredictable or random events have no trends. Therefore, no unpredictable event indicators are possible except incidents and accidents, which will show levels of past risk.

Secondary and Tertiary Safety Factors: Industry Safety Posture

Commercial aviation safety is the dual responsibility of FAA and the airlines. Federal Aviation Regulations (FARs) set the framework for establishing commercial aviation operating practices. Under the current system, many practices tailored to individual carrier needs are allowable through programs approved by FAA Principal Inspectors and Flight Standards District Offices.

The commercial airline industry's operating practices—flight operations, maintenance, and training—are a dominant influence on the traffic environment, aircraft capabilities, and personnel capabilities causal categories discussed above.' These practices, along with the operation of the ATC system, are the secondary safety factors (see box 4-A).

The tertiary safety factors, furthest removed on the accident/incident causal chain, affect the industry operating practices listed above. Industry* philosophy and policy, which differ among airlines, dictate operating decisions. Federal regulatory policy in turn influences industry policy and operating practices. Qualitative assessments of the way operating practices affect safety performance are best made by independent inspectors using objective standards. In theory, FAA airline inspection programs are such assessments, although airline management and labor organizations receive relatively little attention in FARs.

[6] William R. Hendricks, director, Aviation Safety, Federal Aviation Administration, attachment to letter t. OTA, Dec. 18, 1987. The Federal Aviation Administration defines an "operational error" as", . . an occurrence attributable to an element of the air traffic control system which results in less than applicable separation minima between two or more aircraft, or between an aircraft and terrain or obstacles and obstructions as required by FAA Handbook 7110.65 and supplemental instructions. "

An "operational deviation" is ". . . an occurrence where applicable separation minima were maintained but loss in separation minima existed between an aircraft and protected airspace, an aircraft penetrated airspace that was delegated to another position of operation or another facility without prior approval, or an aircraft or controlled vehicle encroached upon a landing area that was delegated to another position of operation without prior approval. "

A "pilot deviation" is ". . . the action of a pilot that results in the violation of a Federal Aviation Regulation or a North American Aerospace Defense Command (NORAD) Air Defense Identification Zone (ADIZ) tolerance."

[7] Manufacturers, through aircraft design and production, influence aircraft capabilities, and noncommercial flyers and Federal policy affect the air traffic environment. These are assumed to be beyond the direct control of the airlines.

[8] "Industry" includes airline management as well as labor unions.

Secondary Safety Indicators

FARs require the reporting of some data relevant to operating practices. For example, air carrier traffic, schedule, and financial information must be periodically submitted to the U.S. Department of Transportation (DOT). These data illustrate differences among carriers and over time, but as currently reported and reviewed, no correlation with safety has been established. Some examples of potential safety indicators are given below.

Flight Operations.—With the increased use of hub and spoke networks and the limits of the ATC system, airline flight crews and maintenance operations have felt new demands. While each airline will handle similar pressures differently, the trends in the indicators are important to understand. Some examples include: aircraft daily utilization (number of hours per day an aircraft is used); departures per aircraft per day; percent of fleet required for daily operations; and percent of flights into high density airspace.

C m
d g

Maintenance.– The aircraft capability indicators discussed previously are applicable measures of maintenance quality, though equipment design and manufacturing quality are important also. Unit maintenance costs can be used, but there are many reasons for variations among carriers and over time, such as productivity and technological changes.

Training.– Possible indicators include the number of hours of a type of instruction per applicable employee and the use of certain nonmandatory but valuable options, such as simulators, cockpit resource management, and wind shear training.

Tertiary Safety Indicators

FAA safety audits for regulatory compliance could indicate airline management attitude, organizational skill, and operational safety. While inspection data are subject to the personal biases of the individual inspectors, the use of objective inspection guidelines and standards, consistent and periodic audits, and varying inspection teams make inspection results valid measures of safety trends. Regulatory compliance data differ from previously discussed indicators in that the exposure parameters will no longer be miles, departures, or hours. Since FAA inspectors examine only a small percentage of an airline's records, aircraft, and operations, a measure of the quantity of inspection is needed in order to normalize the data used for analysis. For example, an inspection of 10 percent of the records of a large carrier would probably find more faults than a 10 percent examination of a small carrier. A measure of a carrier's exposure to inspection, such as the number of inspector man-hours performed or the number of records or operations examined, would be used as the denominator in the indicator ratio. The number of violations per inspection man-hour is an example of a regulatory compliance measure.

With appropriate guidelines, the quality of management practices could be measured by inspector assessment and ranking of certain aspects of airline operations. For example, two airlines may meet all Federal standards, but one may still be noticeably "safer" than the other. Objective standards are needed to permit consistent analyses across industry and time.

DATA RESOURCES

The Federal Government collects vast amounts of aviation data to support its responsibility for overseeing aviation safety, and automated systems are required for effective data processing. However, OTA research indicates that the analytical qualities of electronic data management systems and their data vary significantly among and within the Federal agencies dealing with aviation safety. The amount and caliber of safety data are significantly better for commercial aviation than for other transportation modes, but major barriers prevent effective use of the data. While frequently-cited accident and fatality statistics reflect past risk, a comprehensive program using Federal databases could identify and monitor changes in commercial aviation safety in a more timely manner. The central difficulties of such a program are:

- the consistency and availability of appropriate safety data,
- the accessibility and compatibility of various data systems, and
- an emphasis on administrative purposes in the design and use of the databases that makes analysis difficult.

These problems are not new. A 1980 General Accounting Office (GAO) report stated that FAA had not been effective or timely in developing systems to identify safety hazards.[9] The report futher explains that:

> . . . although FAA's hazard identification efforts have been numerous and varied, they have been hindered by insufficient information gathering, limited analysis that has not fully employed state of the art capabilities, and an inadequately planned and coordinated agency approach. "[10]

A "blue-ribbon" committee of the National Research Council concurred with these findings and recommended that ". . . the FAA accelerate its development of an effective information-gathering and data system. "[11]

[9]U.S. Congress, General Accounting Office, *How To Improve the Federal Aviation Administration's Ability To Deal With Safety Hazards,* GAO/RCED 80-66 (Washington, DC: Feb. 29, 1980), pp. 5-17.

[10]Ibid. D. 5.

[11]National Research Council, Assembly of Engineering, Committee on Federal Aviation Administration Airworthiness Certification Procedures, *Improving Aircraft Safety: FAA Certification of Commercial Passenger* Aircraft (Washington, DC: National Academy of Sciences, 1980), p. 66.

Using the safety indicator theory developed earlier in this chapter, OTA reviewed a wide assortment of Federal aviation safety databases in an effort to document changes in commercial aviation safety during the past decade. A number of these databases contain ostensible safety indicator data (see table 4-2), but in practice, the nonaccident information has numerous shortcomings and is of limited use for safety trend analysis. An overview and assessment of each of the databases listed in table 4-2 are presented in this section, and uses and potential uses for these databases are given. (OTA analyses of these and other data are presented in chapter 5.)

Federal Safety Data Resources

DOT, which has regulatory responsibility for transportation safety, maintains the largest amount of aviation data. Within DOT, FAA, which monitors all aspects of aviation safety, and the Research and Special Programs Administration (RSPA) are responsible for the collection and management of safety and economic-related information. NTSB and the National Aeronautics and Space Administration (NASA) also keep specialized aviation safety data.

FAA

FAA is responsible for promoting aviation safety, achieving efficient use of airspace, operating an air traffic control system, and fostering air commerce. In support of these missions, FAA collects a wide range of aviation information and operates over 280 automated data systems.[12] Three organizations within FAA, the Associate Administrator for Aviation Standards, the Associate Administrator for Air Traffic, and the Office of Aviation Safety collect and manage most of the safety-related data.

Associate Administrator for Aviation Standards

Aviation Standards (AVS) personnel, working out of regional and field offices across the United States, collect and review large quantities of data

[12]U.S. Department of Transportation, Federal Aviation Administration, information Resources Management Plan, Volume *II:* Systems *Plan FY87-FY89* (Washington, DC: December 1986), p. 167.

Table 4-2.—Federal Aviation Safety Databases

Data type	Database	Federal agency	Earliest year[a]	Storage system for historical data
Accident/incident	Aviation Accident Data System	NTSB	1982	Digital DEC-10; published reports
Accident/incident	Accident Incident Data System	FAA	1978	Boeing Computer Services IBM 3084; Data General MV-15000
Incident	Aviation Safety Reporting System	NASA	1975	Battelle Columbus Laboratories: VAX integrated computer cluster
Incident	Near Midair Collision Database	FAA	1980	IBM/AT; published reports
Incident	Operational Error Database	FAA	1985	IBM/AT; published reports
Incident	Pilot Deviation Database	FAA	1985	IBM/AT; published reports
Mechanical reliability	Service Difficulty Reporting System	FAA	1978	Boeing Computer Services IBM 3084; Data General MV-15000; published data
	Air Operator Data System	FAA	1980	Boeing Computer Services IBM 3084; Data General MV-15000; published data
Traffic levels	Air Traffic Activity Database	FAA	Previous 18 months	Published reports
Operational practices	Air Operator Data System	FAA	1980	Data General MV-15000; published data
	Air Carrier Statistics Database	RSPA	1988	Digital DEC-10; published reports
Inspection results	Work Program Management System	FAA	1987	Data General MV-15000
Violation/enforcement actions	Enforcement Information System	FAA	1983	Boeing Computer Services IBM 3084: Data-General MV-15000

KEY: NTSB - National Transportation Safety Board; FAA = Federal Aviation Administration; NASA = National Aeronautics and Space Administration; RSPA = Research and Special Programs Administration.

[a]Earliest year for data stored electronically.

SOURCE: Office of Technology Assessment, 19S8

as well as certificate aircraft, airmen, and airlines; oversee and enforce Federal Aviation Regulations; and investigate aircraft accidents and incidents. Many of these data are entered into the numerous databases maintained in Oklahoma City at the Mike Monroney Aeronautical Center and the Aviation Standards National Field Office (AVN).

The AVN and Aeronautical Center databases, used primarily to support administrative AVS tasks, reside on various computer hardware. Most of the data systems are hosted by the Aeronautical Center's IBM-3084 mainframe or AVN'S Data General MV-15000 minicomputer, though some operate on the MV-8000'S located at each regional office, the Burroughs B20 workstations distributed throughout FAA or the Transportation System Center's Digital DEC-10. Some of the systems, while required for the daily operation of AVS, are less important for analyzing system safety. Examples include databases containing airmen and airline certification records, medical records, aircraft registry and airworthiness information, and regulatory history. AVN does maintain four data systems which are used, or can be used, for safety analyses. These databases, containing information on aviation accidents and incidents, mechanical difficulties, regulation violations, and aircraft utilization and reliability, will be discussed in this section.

Some of the limitations of these independent and incompatible safety data systems have been recognized by FAA. The FAA Information Resources Management Program Office described the problems that arose from the lack of coordination during the development of the specialized data systems:

> Little consideration was given to the information requirements of other organizational elements within the agency. This approach has resulted in a number of fragmented data systems that contain nonstandardized data, having limited access, and do not satisfy the needs of all users. In addition, the

data contained in these systems are not always current and lack the accuracy necessary to effectively meet the agency's program objectives.[13]

FAA is developing the Aviation Safety Analysis System (ASAS) to integrate and standardize current and future databases and maintain them on a central host computer linked via a telecommunication network to workstations located at all AVS facilities. An overview of ASAS is given later in this section.

The hardware and software compatibility problems limit the ease with which data are transferred between field personnel and AVN. With the exception of enforcement and inspection information, at present, data can be entered into the systems only in Oklahoma City. While this limits input errors (effectively, only one or two people enter data per database), timely responses are impossible. Though the field offices have access electronically to most of the systems, the databases are so intricate that data requests usually require processing by the limited number of AVN personnel.

Another option available to AVS personnel, as well as to any interested party, is a commercial timeshare network that presently contains three of the safety data systems. Operated by Boeing Computer Services, the system enables users to access the complete on-line FAA databases for accidents and incidents, service difficulty reports, and enforcement cases. Historical data, from as many as 5 previous calendar years, can be extracted in standard or custom-designed formats.

FAA Accident Incident Data System.–Accident data provide the key means of measuring aviation safety. An understanding of underlying accident causes and trends leads to preventive measures. Responsibility for investigating all civil aircraft accidents in the United States rests with NTSB,[14] though authority is delegated to DOT and FAA for certain accidents.[15] Both FAA and NTSB officials collect accident data, but NTSB alone determines probable causes. FAA is responsible for ensuring aviation safety, and investigates accidents primarily to assess whether corrective action is required in the aviation system. In January 1984, both agencies began using common forms, the NTSB series 6120, for the reporting of accident data. While efforts are underway to develop a joint NTSB/FAA accident database, both agencies currently maintain separate data systems. There is considerable, but not complete, overlap between the two systems. The NTSB Aviation Accident Data System contains all U.S. civil aircraft accidents and selected incidents, while the FAA Accident Incident Data System (AIDS) has fewer accident records, but substantially more incident data than the NTSB system.

AIDS contains general aviation and air carrier incidents dating from 1978, and general aviation accidents from 1973. In 1982, as a step toward the common NTSB/FAA accident database, air carrier accident information was introduced to the system. Though the NTSB database is considered the definitive source for aircraft accident data, AIDS is more accessible to FAA personnel on a daily basis. Copies of completed accident reports are forwarded from NTSB to AVN, where the data are entered into the Data General MV-15000 minicomputer.

While NTSB investigators also use the common series 6120 forms for reporting incidents.[16] AVS personnel use the less detailed FAA Form 8020-5. The completed FAA reports are sent to Oklahoma for processing and review, where contract personnel classify the incidents and assign probable cause factors. Other AVN employees encode and enter the incident information into the data system. However, the reports are not verified and no procedure is in place for ensuring consistent reporting from the field. OTA found substantial variation in the incident reporting rates among the FAA regions (see chapter 5).

AIDS data are available to FAA regional offices and headquarters via the commercial computer timeshare system operated by Boeing Computer Services or by printouts from AVN. OTA finds that while separate analyses of incident or accident data

[13] U.S. Department of Transportation, Federal Aviation Administration, *Information Resource Management Plan, Volume I: Strategic Overview* (Washington, DC: December 1986), p. 22.

[14] 49 CFR 800.3 (Oct. 1, 1987).

[15] 49 CFR 800, app. (Oct. 1, 1987).

[16] By regulation, aircraft operators must notify the National Transportation Safety Board of five types of incidents (49 CFR 830.5), which may be investigated depending upon the circumstances and National Transportation Safety Board workload. This results in approximately 30 air carrier reports per year from the Board, compared with over 1,400 reports by Federal Aviation Administration investigators.

are possible, comparisons of accidents and incidents are difficult because FAA uses different terminology in classifying incidents than NTSB uses in accident/incident reports. OTA devised an algorithm for reorganizing FAA data into the NTSB format, and requested that AVN use it in extracting commercial aircraft accident and incident data. AVN provided little useful automated support. The algorithm required searches and combinations of AIDS data fields; OTA received unwieldy printouts of a portion of the data requested. Even if the missing information were available, extensive manual processing would be necessary to format the data.

While NTSB and NASA provide detailed analyses of the accident and incident data they maintain, FAA examines air traffic incident data only. In 1984, the Safety Analysis Division of AVS was moved to the newly formed Office of Aviation Safety. Consequently, AVS does not have the resources to analyze air carrier incident or other data maintained in Oklahoma City. While sufficient information, such as causes and factors, is collected, it is not used in measuring and monitoring aviation system safety or to assist in setting regulations.

Enforcement Information System.–Theoretically, trends in the airline industry safety posture could be determined from the results of regulatory compliance audits performed by FAA inspectors. To accomplish this, the number and type of violations per carrier and some measure, such as inspector man-hours, of each airline's exposure to inspections would be needed. However, while all enforcement actions are tracked and recorded in the Enforcement Information System (EIS), little information is available on the number of inspections performed or the amount of time spent on them. [17]

EIS, which is managed by AVN on the MV-15000 minicomputer in Oklahoma City, was designed and is used primarily for administrative purposes. In support of AVS and General Counsel personnel, EIS tracks the complete history of each enforcement case and keeps copies of all documentation. Electronic records are available from 1963 to present. Because of the sensitivity of the data, only closed cases are available to the public.

[17] U.S. Congress, General Accounting Office, *Aviation Safety: Needed Improvements in FAA's Airline Inspection Program are Underway,* GAO/RCED 87-62 (Washington, DC: May 1987), pp. 24-38.

EIS is the only AVN system that allows input directly from the field offices; the others require that the field personnel send paper copies of the data to Oklahoma City for processing by AVN personnel.

Service Difficulty Reporting System.–The mechanical reliability of aircraft and components is monitored by AVN analysts through the Service Difficulty Reporting System (SDRS). Reports, required by regulation,[18] are filed by air carriers, repair stations, manufacturers, FAA inspectors, and others concerning specific types of aircraft failures or malfunctions. These reports arrive at AVN in paper form where the data are encoded and entered into the MV-15000 minicomputer.

While containing data for over 10 years, SDRS is most useful for detecting short-term safety problems. The SDRS program automatically tracks trends in reports according to aircraft and component type. If the monthly or annual trend in reports exceed a pre-set value, then the system automatically alerts AVN analysts. An airworthiness directive, warning, or alert is issued to the public if, after review, the trend alert proves serious.

SDRS data are rarely used for long-term analyses. Due to the nature of the system, long-term adverse trends avoid detection since they have such shallow slopes they do not set off the alerting system. Also, since mechanical difficulties are often discovered during maintenance inspections, the frequency and depth of these inspections, along with the willingness of the airlines to file reports, affect the SDRS database.

Air Operator Data System.–AVS personnel must frequently refer to information about air carriers and other commercial operators and the structure of their organizations, fleets, and facilities. While such information is available in fragments from many sources within DOT, the Air Operator Data System (AIROPS) attempts to consolidate the vital data available from within FAA. Of interest for safety analysis are data involving aircraft operations, such as utilization and engine reliability.

Unlike other AVS data gathering efforts discussed (accident/incident, enforcement, service difficulties), there is no regulatory requirement for air carrier

[18] 14 CFR 121.703 and 14 CFR 135.415 (Jan. 1, 1987).

reporting or FAA collection of "air operator" data as such. " Air carrier inspectors, though, follow general guidelines for collecting the data monthly. They send air operator data to Oklahoma City by mail for processing. While AVN employees ensure accurate transcription of data, there are no procedures in effect for ensuring accuracy at the source. The National Air Transportation Inspection (NATI) Program, which relied on AIROPS for many of its activities, discovered many errors in the data. The NATI report concluded that the Air Operator Data System is ". . . in need of corrections and enhancements."[20] Data have been collected and published in the monthly Air Carrier Aircraft Utilization and Propulsion Reliability Reports since the 1960s, though due to contractor problems, no reports were released between January and August 1987.[21]

Air operator data provide the opportunity for analyzing certain air carrier operating practices, by individual company or industry wide. When used in conjunction with other system information, daily utilization data give one view of the amount of schedule pressure placed on aircraft fleets. Engine reliability data, the basis for overwater flight certification, indicate the final product of equipment design and airline maintenance and operating procedures.

Work Program Management Subsystem.–FAA's struggles to modernize its air carrier inspection program are documented in a recent GAO report.[22] FAA senior management and safety analysts knew little about the inspections being performed during the post-deregulation period. The only attempt at using inspection results for analysis followed the NATI Program in 1984. The NATI Task Force, comprised of former FAA inspectors, reviewed the NATI reports and found that over 20 percent of the carriers analyzed had a "less than desirable compliance posture,"[23] and that FAA inspector surveillance and enforcement needed improvement.[24] The NATI Program also identified FAA problems in collecting and managing inspection data.[25]

Even before NATI occurred, FAA was planning an automated system for tracking the inspection program. However, the Work Program Management Subsystem WPMS), implemented in October 1984, has been plagued by problems. The microcomputers, on which the inspection data are entered, have insufficient capacity for the system requirements. Additionally, there are not enough of the computers to go around. Moreover, FAA installed inadequate software in the system, limiting the type and extent of the inspection data available for analysis.

Changed in October 1986, the current software provided some usable data in fiscal year 1987. FAA's Western Pacific Region has successfully utilized WPMS for inspection efforts, though it still cannot access the central computer in Oklahoma City. WPMS has aided FAA's geographic inspection concept by allowing field inspectors throughout the United States to send inspection results directly to the carrier's respective principal inspector.

Though designed primarily as a tool for managing the FAA inspection program, WPMS can potentially be used for safety analysis. WPMS data, centrally stored at AVN, enable a compilation of inspection results and a measure of exposure (inspector-hours).

Using the Data Systems for Analysis

OTA found few presentations, let alone analyses, of the safety data contained in the AVS data systems. Moreover, the systems are difficult to use for safety analyses for two fundamental reasons. First, AVN exercises little quality control of data collection and reporting, because it has neither the manpower nor the imperative to do so. Furthermore, no plans are underway for ensuring that FAA field personnel or airlines collect and report accurate data.

[19] Air carriers must report organizational, operational, and financial data to the Research and Special Programs Administration's Office of Aviation Information Management (and previously to the Civil Aeronautics Board) as required by 14 CFR 241 and 14 CFR 298. Certain engine problems must be submitted via mechanical reliability reports as stated in 14 CFR 121.703 and 14 CFR 135.415.

[20] U.S. Department of Transportation, Federal Aviation Administration, "National Air Transportation Inspection Program," report for the Secretary, Mar. 4-June 5, 1984, p. 36.

[21] The data were consolidated and released in special reports in fall 1987.

[22] General Accounting Office, op. cit., footnote 17.

[23] U.S. Department of Transportation, Federal Aviation Administration, "Memorandum on Evaluation of National Air Transportation Inspection Program Inspection Reports," April 1985, p. 37.

[24] Ibid, p. 41.

[25] Federal Aviation Administration, op. cit., footnote 20, p. 23.

Second, extracting useful data from an established database requires not only an understanding of the safety problem to be analyzed, but knowledge of the limitations of the computer systems and the intricacies of the data fields. These AVN data systems were not designed as analytical tools, and AVN personnel are not trained analysts. FAA plans to address some aspects of this problem by implementing the Aviation Safety Analysis System (ASAS), which, as envisioned, will consolidate and standardize new and existing safety databases. In contrast to the present system, FAA personnel without extensive training in computer programming will have access to a wide range of safety data via desktop workstations.

ASAS was conceived in 1979 to build upon the general office automation program for regional and field offices then in development at FAA. New office equipment, proposed as part of the automation program, was to have sufficient processing and network capabilities for an integrated safety data system. The numerous compatibility and communication difficulties created by the data systems then in use (for the most part, still in use) at FAA were to be addressed by ASAS. An ASAS Program Office was established in 1982 and a long-term phased development plan was proposed. The initial phase will integrate and standardize current data systems. Subsequent phases will implement and develop new databases.

Photo **credit:** *Federal Aviation Administration*

FAA inspectors and safety analysts need ready access to complete and accurate data.

The types of ASAS databases fall into four categories: 1) airworthiness data; 2) regulatory data; 3) operational data; and 4) organizational information. Airworthiness data are mainly historical information on aircraft, such as mandatory modifications specified by FAA. Regulatory data consist of background information, such as Notices of Proposed Rulemaking, legal opinions, and previous regulations. Data describing the aviation environment are included in the operational category. These databases track airmen, aircraft, and operators along with accidents, incidents, mechanical reliability reports, and enforcement actions. The work management subsystems to monitor AVS tasks, such as airline inspections, fall into the category of organizational information.

ASAS will alter many of the tasks currently performed by AVS personnel. Data will be entered and validated where it is collected and generated, at the field office level. This increase in employee exposure to automated systems implies a need for substantial training and for user-friendly equipment and software. The problems with WPMS, discussed earlier, illustrate the need for proper training and technology. It is also proposed that field personnel will be able to perform their own data analyses using information from several databases through analytical software packages.

Associate Administrator for Air Traffic

In managing the National Airspace System (NAS), Air Traffic (AAT) personnel control traffic, operate facilities, and develop procedures and standards for airways, airspace, and flight operations. On a daily basis, information is collected and reviewed concerning air traffic levels, NAS status, system errors, controller errors, pilot deviations, and delays, although most of the data are entered into automated systems only after reaching specific offices within FAA headquarters. Other offices, regions, or field facilities within AAT do not have ready access to many of these systems.[26] However, Office of Air Traffic Evaluations and Analysis specialists monitor every report on operational errors, NMACs,

[26] U.S. Department of Transportation, Federal Aviation Administration, *Information Resource Management Plan, Volume 1: Strategic Overview* (Washington, DC: October 1985), p. 14.

and pilot deviations and communicate findings to the field facilities.[27]

While AAT tracks and analyzes air traffic safety data, it does not manage the data systems dealing with incidents or system-wide operational information of interest to this study. The Office of Aviation Safety (discussed in the next section), handles the incident data while the air traffic activity data are processed by the FAA Office of Management Systems. The Office of Air Traffic Evaluations and Analysis is developing its own data system, the Operational Error Reporting System, to receive and track operational error reports in a timely fashion. The system has been on-line, linking a number of regional offices with headquarters, since June 1987.

Air Traffic Activity Database.–An essential exposure measure for air safety analysis is the level of traffic. One parameter, departures, is the best exposure reference for general safety comparisons. While departure data are available for specific carriers from Civil Aeronautics Board records and RSPA, system-wide traffic data, including departures, are available from the Air Traffic Activity Database.

Air traffic control personnel keep track of the daily activity at ATC facilities. Monthly summaries of various operations, including the number of takeoffs and landings at airports with control towers and the number of aircraft handled by radar control facilities, are submitted to the Office of Management Systems in FAA headquarters. There the data are encoded for entry into the Boeing Computer Services System, where they are processed and crosschecked. Due to the large volume of monthly data, the Boeing system is not used for analysis or storage, but as a tool for preparing summary reports. Annual Air Traffic Activity Reports are published and are available to the public.

Facility, region, or system-total data are available, with tables categorizing information by aircraft operator (air carrier, air taxi, general aviation, and military). This study used historical tower activity data to illustrate the growth of hubs and as the exposure reference for air traffic incidents. The number of aircraft handled by en route radar controllers is an alternate measure of traffic trends.

[27]B Keith Potts, associate administrator, Air Traffic, Federal Aviation Administration, personnel communication, Dec. 22, 1987.

Office of Aviation Safety

Reporting directly to the FAA Administrator, the Office of Aviation Safety conducts accident investigations, safety analyses, and special programs. In this role, it monitors or manages several databases. The Office of Aviation Safety operates the National Airspace Incident Monitoring System, an automated system containing NMAC, operational error, and pilot deviation databases. FAA maintains contact with the NASA-administered, but FAA-funded, Aviation Safety Reporting System through the the Safety Analysis Division within the Office of Aviation Safety.

Near Midair Collision Database.–FAA learns about NMACs primarily from pilot reports, though air traffic controllers, passengers, and ground observers also serve as notifiers. In each case, a preliminary report is filed and must be investigated by FAA within 90 days.

Although the AVS Accident Incident Data System tracks NMACs, they are not included in its database. All incident reports involving air traffic operations, including NMACs, end up in the Office of Aviation Safety. There, the data are encoded and entered into an IBM/AT personal computer system located at FAA headquarters. NMAC information from 1980 to the present is available in the system. FAA has had widely publicized difficulties with its NMAC data, and instituted a monitoring procedure in 1985 to ensure proper handling of NMAC reports. An interagency task group consisting of FAA, NASA, and the Department of Defense was formed in 1986 to review existing NMAC data and recommend ways to reduce the midair collision threat. The recommendations cover equipment, airspace structure, data reporting, and pilot training. Additionally, the Office of Aviation Safety is presently conducting a number of NMAC studies.

Operational Error Database.–The loss of legal flight separation around an aircraft which is attributed to the ATC system is an operational error (see footnote 6). For example, during en route operations, controllers are required to keep aircraft apart by 5 miles horizontally and 1,000 feet vertically for flights below 29,000 feet and 2,000 feet vertically for flights above. Operational deviations, generally less serious than operational errors, do not involve loss of separation between two aircraft, but result from an aircraft passing too close to a restricted airspace or landing area.

From 1983 to 1985, FAA instituted two changes. First, the enroute ATC computers were reconfigured with the Operational Error Detection Program which automatically records and reports any loss of proper separation for aircraft in the system. Second, the responsibility for maintaining an operational error report database was shifted to the Office of Aviation Safety. Preliminary reports of operational errors and deviations are filed from the ATC facility within 48 hours after the event's occurrence. All reported operational errors and deviations are investigated, and depending on the outcome, a final report is submitted. Personnel from the Office of Aviation Safety encode and enter preliminary and final report data into the IBM/AT.

Pilot Deviation Database.–An ATC facility that observes a pilot deviation is responsible for reporting it to the appropriate Flight Standards office for investigation. Prior to 1985, incidents involving pilot deviations were entered into AVN'S Accident Incident Data System, though they were not specifically categorized as pilot deviations. Presently, the results of pilot deviation investigations are sent directly to the Office of Aviation Safety where the data are entered into an IBM PC. The Office of Aviation Safety is responsible for tracking and reporting trends in pilot deviations, and published its first statistical report of pilot deviations in October 1987.[28] Similar to the operational error data, pilot deviation information stored electronically extend back only to 1985.

NTSB, in a special investigation of runway incursions, found that as with operational errors, many pilot deviations are not being formally reported but are resolved informally at the ATC facility involved.[29] Additionally, prior to 1985, reports reaching Flight Standards were investigated primarily to determine violation and enforcement actions against the pilot involved, not for safety analysis.[30] The number of pilot deviation reports processed by the Office of Aviation Safety is increasing every year (over 2,500 in 1986), though how much of that growth should be attributed to changing reporting practices is open to question.

National Transportation Safety Board

NTSB is responsible for investigating all aircraft accidents and certain incidents, determining their probable causes, and making recommendations to FAA. It keeps an extensive database of accident information in an automated system and publishes accident reports and the results of other special investigations.

Aviation Accident Data System.–Since its inception in 1967, NTSB has kept records of civil aircraft accidents.[31] The current automated database, the Aviation Accident Data System, contains information on aviation accidents and incidents. Primarily designed for administrative purposes, the system does have analytical capabilities. NTSB publishes Annual Reviews of Aircraft Accident Data and occasional Special Studies, which are supported by statistical analyses accomplished with the data system.

The NTSB Aviation Accident Data System contains information on every known civil aviation accident[32] in the United States. Selected incidents, as listed in 49 CFR 830.5, are also included in the database. The system encompasses data from 1962 to the present, though changes were made in reporting methods during this period. A single format was used until 1982, when the procedure and report form was revised. The documentation was again changed in 1983, when NTSB accident investigators began submitting data in the format that was eventually adopted as NTSB series 6120.4. The data from the reports are entered into the computer, along with the findings of probable cause and contributing factors. Computer searches are possible with any data block or group of blocks as selection criteria.

Differences in data formats impose some restrictions on possible computer-assisted analyses. For example, in 1982, NTSB changed its method of clas-

[28] U.S. Department of Transportation, Federal Aviation Administration, *Selected Statistics Concerning Reported Pilot Deviations (1985-1986)* (Washington, DC: October 1987).

[29] National Transportation Safety Board, *Special Investigation Report-Runway Incursions at Controlled Airports in the United States*, NTSB/SIR-86/01 (Washington, DC: May 6, 1986), p. 8.

[30] Ibid, p. 8.

[31] From 1940 to 1967, the Civil Aeronautics Board investigated accidents.

[32] Accidents involving only military or public-use aircraft are not usually investigated by the National Transportation Safety Board.

sifying accidents. Accidents are now categorized by the first "occurrence" in the sequence of events that led to the accident. Earlier, groupings were made by the accident "type." NTSB has developed a matrix for comparing occurrences and types. For broad safety studies, the effect of the format changes is small. While the collection of data has essentially remained the same, the latter format allows a more detailed analysis of accident circumstances.[33]

NASA

NASA, which provides and supports aviation research and development, administers the confidential and voluntary Aviation Safety Reporting System (ASRS). ASRS is designed to encourage reports by pilots and air traffic controllers concerning errors and operational problems in the aviation system, by guaranteeing anonymity and immunity from prosecution for all reporters. ASRS data can provide an alternate Federal insight into the nature and trends of aviation incidents.

NASA Aviation Safety Reporting System.– ASRS is a joint effort by FAA, NASA, and the Battelle Memorial Institute to provide a voluntary reporting system where pilots, controllers, and others can submit accounts of safety-related aviation incidents. The system is funded mainly by FAA, administered by NASA, and maintained by Battelle. Reports are sent to the ASRS office at NASA Ames Research Center and the data are analyzed and entered into a computer by employees of Battelle. The database is maintained at Battelle Columbus Laboratories in Ohio.

Prior to the establishment of ASRS in 1976, attempts at providing voluntary incident reporting programs met with little success. Potential reporters feared liability and disciplinary consequences. Even after FAA introduced its Aviation Safety Reporting Program (ASRP), which offered limited immunity and anonymity to participants, few reports were submitted. The aviation community feared that FAA, responsible for setting and enforcing regulations, would misuse the data. FAA acknowledged these concerns and transferred control of ASRP to a neutral third party, NASA. A Memorandum of Agreement was executed between FAA and NASA in August 1975, establishing ASRS. The Agreement provided for a limited waiver of disciplinary action, confidentiality of reporting sources, and an Advisory Committee comprised of representatives of the aviation community. ASRS became operational on April 15, 1976.[34]

Voluntary reports, useful for understanding the nature of incidents, are somewhat deficient in indicating prevalence or frequency. Therefore, ASRS was planned as an "analytical rather than a descriptive system."[35] The ASRS report form (NASA Form ARC 277) was designed to gather the maximum amount of information without discouraging the reporter. Structured information blocks and key words are provided, not only to guide the reporter, but to aid subsequent data retrieval and research. Narrative descriptions are encouraged. Space is provided for the reporter's name, address, and telephone number. This permits NASA to acknowledge the report's receipt by return mail, and also allows the Battelle analyst to contact the reporter for followup data. Information that identifies the reporter is deleted before being entered into the computer.

Under the guidance of NASA, Battelle receives the incident reports, processes and analyzes the data, and publishes reports of the findings. Human factors in aviation safety, a continuing concern at the NASA Ames Research Center, were a major consideration in ASRS development. The data analysts, primarily experts in aircraft operations and air traffic control, provide insight into the nature of the human error or other underlying factors in the incidents. Although the reports are encoded in detail, the complete narrative text of each report is retained for later re-evaluation.

Because ASRS is voluntary and reporters are deidentified, a concerted effort among a number of

[33]National Transportation Safety Board, *Annual Review of Aircraft Accident Data, U.S. Air Carrier Operations, Calendar Year 1982*, NTSB/ARC-86/01 (Washington, DC: n.d.), p. 1.

[34]William D. Reynard, Aviation Safety Reporting System, in U.S. Congress, House Committee on Science and Technology, Subcommittee on Investigations and Oversight, *Aircraft Safety Technologies* (Washington, DC: U.S. Government Printing Office, Nov. 23, 1985), p. 29.

[35]Charles E. Billings, M. D., the National Aeronautics and Space Administration Ames Research Center, "Human Factors in Aircraft Incidents: Results of a 7-Year Study," *Aviation, Space, and Environmental Medicine*, October 1984, p. 961.

individuals can distort the database. For example, air traffic controllers at certain facilities increased their reporting of incidents associated with a display system that they wanted upgraded. This reporting campaign ended with the air traffic controllers strike in August 1981.[36]

RSPA

The Office of Aviation Information Management of RSPA assumed the former Civil Aeronautics Board's responsibility for collecting data on airline operations, traffic, and finances beginning in 1985. Airlines submit data periodically in accordance with 14 CFR Parts 217, 234, 241, 291, and 298. While these data do not directly indicate safety, they do provide measures of exposure such as departures, hours, and miles. However, the airline categories for exposure data reporting do not correspond to the operating categories used by NTSB for classifying accidents, resulting in some gaps and inaccuracies in statistics. Financial statistics also have potential uses in analyses, since many in industry and government believe that economics influence safety to some degree.

Air Carrier Statistics Database.–Part 217 Reporting Data Pertaining to Civil Aircraft Charters performed by U.S. and Foreign Air Carriers (14 CFR 217) requires U.S. and foreign air carriers to file traffic data on any civilian international charter flight flown to or from the United States in large aircraft (over 60 seats or 24,000 pounds of payload). The information reported quarterly shows the charter passengers or tons of cargo flown between the origin and the destination point of the charter. The information is reported by aircraft type by month.

Part 234 Airline Service Quality Reports (14 CFR 234) requires 14 certificated U.S. air carriers (a carrier with more than 1 percent of total domestic scheduled passenger revenues) to file monthly flight performance information for every domestic nonstop scheduled passenger operation to or from the 27 largest U.S. airports (airports with more than I percent of domestic scheduled passenger enplanements). Carriers are voluntarily reporting data for each domestic scheduled flight instead of limiting their reporting to the 27 airports. For the origin airport of each nonstop segment, the carrier reports published departure times versus actual departure times; for the destination airport, the published arrival times versus the actual arrival times are reported. This information is reported by date and day. Flights delayed because of mechanical reasons, as defined by FAA, are not reported.

Part 241 Uniform System of Accounts and Reports for Large Certificated Air Carriers (14 CFR 241) prescribes the accounting and reporting regulations for large U.S. certificated air carriers (Section 401 certificate). A large carrier is defined as a carrier operating aircraft which are designed to accommodate more than 60 seats or a cargo payload of more than 18,000 pounds. All large carriers, according to the level of their operations, as measured by annual operating revenues, are placed into one of four groups: Group I Small ($10 million and under), Group 11 Large ($10,000,001 to $75 million), Group III ($75,000,001 to $200 million) and Group IV (over $200 million), The amount and detail of reporting increases with carrier size. Data are submitted on individual schedules of the DOT Form 41 Report or by electronic media. In general, carriers report exposure data such as aircraft departures, hours, miles, and passenger enplanements in total and by aircraft types. A broad range of financial data including categories of revenues and expenses are also reported, with those related to operations being indexed by aircraft type.

Part 291 Domestic Cargo Transportation (14 CFR 291) prescribes the reporting required of carriers providing domestic all-cargo operations exclusively under Section 418 certificates. These carriers are required to file Form 291-A, a one page annual report, which contains seven profit and loss items, and seven traffic and capacity items. The data are not reported by aircraft type.

Part 298 Exemptions for Air Taxi Operations (14 CFR 298) prescribes the reporting for small certificated air carriers (Section 401 certificate) and commuter air carriers. Both classes of carriers operate aircraft which are designed for 60 seats or fewer or for 18,000 pounds of cargo capacity or less. A commuter air carrier is defined as a special classification of air taxi operator that provides passenger service consisting of at least five roundtrips per week be-

[36] William D. Reynard, chief, Aviation Safety Reporting System, Personal communciation, Feb. 23, 1988.

tween two or more points. Commuters report only traffic exposure data totals with no indexing by aircraft type. Small certificated air carriers submit the same information as commuters plus revenue and expense data. The direct expense data and three operational items (block hours, departures, and gallons of fuel issued) are indexed by aircraft type on small certificated air carrier reports. Air taxi operators which are not commuters have no reporting requirements.

Various reports including electronic submissions are sent monthly, quarterly, semiannually, and annually to the Office of Aviation Information Management, where the data are entered into the Amdahl computer located in the DOT headquarters building in Washington, DC. Most of these data are published or loaded on magnetic tapes and are available to the general public by ***subscription.***

CONCLUSIONS AND OPTIONS

No single measurement or statistic provides a complete picture of commercial aviation safety. While accident and fatality statistics are the best measures of long-term past risk in commercial aviation, they are of limited value over short periods of time and are not suitable monitors of short-term effects of policy decisions. For example, the consequences of recent rulings requiring collision avoidance systems on commercial transports and transponders on many general aviation aircraft may not be apparent in the accident data for 5 years or more.

Nonaccident safety data, while not substitutes for accident and fatality data, are valuable supplements. If properly collected and maintained, nonaccident data can help identify and estimate the magnitude of safety problems and permit the monitoring of safety programs. OTA concludes that nonaccident data must be used in short-term safety analyses.

FAA has made great strides in recent years in collecting and analyzing air traffic incident data. Indeed, OTA found FAA's air traffic data to be the most useful nonaccident indicators of system safety. However, since the air traffic system is so safe, only a fraction of the commercial aviation accidents and fatalities are caused by the air traffic environment. Consequently, additional nonaccident data are required for tracking changes in commercial aviation safety. OTA finds that FAA programs to identify and monitor changes in the commercial aviation safety system need upgrading.

With the exception of airline inspection records, sufficient data for better monitoring and assessing of commercial aviation safety are collected by or are available to Federal aviation authorities. However, FAA quality control programs need improvement to ensure accurate and consistent data collection and reporting. For example, the FAA computer center in Oklahoma City, which maintains most of the air carrier-specific information, does not verify incoming data. Furthermore, most of the databases are designed primarily for recordkeeping; this constrains, but does not prohibit, analysis,

OTA found the analytical capabilities of both the personnel and the data system at NTSB to be valuable resources. NTSB could readily provide published reports or customized computer printouts; much of the accident data used in this study was supplied by NTSB. **OTA** found that while both NTSB and FAA maintain accident/incident air carrier specific databases and are under tight staff restrictions, the close coordination among NTSB data system managers, analysts, and field person. nel enables NTNB to use its data system effectively for analysis in contrast to FAA's system in Oklahoma City.

The FAA electronic systems required for processing the vast amount of data collected are adequate storage media, but their flexibility and utility for safety analysis vary widely. Experienced safety analysts, the eventual system users, took part in the design of the NASA ASRS and remain involved in the processing and encoding of data. OTA found ASRS data, along with FAA air traffic information, to be the most valuable incident data on commercial aviation that it reviewed. ASRS stands as an excellent example of how to develop and manage an aviation safety data system. OTA found that the close working relationship among data

managers and analysts allows ASRS to be used for a wide range of accident prevention efforts. The system could serve as a useful model for Aviation Standards data systems, which were configured to accept data from report forms poorly designed for computer input. Additionally, the FAA computer center staff, while knowledgeable about and competent in using the systems, are not trained analysts. To compound problems, FAA management structure reflects the fragmented nature of the FAA data systems. Three separate FAA organizations have safety data responsibilities, and databases, data terminology, and automated systems are often incompatible within and among these organizations.

The few FAA studies that use nonaccident data appropriately have come primarily from the Office of Aviation Safety. Recent studies by this office focused on ATC system difficulties, such as near midair collisions, air traffic controller errors, and pilot deviations. On the other hand, the Office of Aviation Safety has had little success in using the AVS data systems and their air carrier information. For example, the Office of Aviation Safety prepares the ***Annual Report*** *on the Effect of the Airline Deregulation Act on the Level of Air Safety,* which does not present or appropriately analyze available nonaccident statistics. The effect of airline operating or management practices, or changes in those practices, on commercial aviation safety are rarely addressed in FAA studies. Air carrier-specific information systems, such as the Work Program Management Subsystem and the Air Operator Data System, are essential tools for properly trained field office personnel in support of AVS's commercial aviation oversight role. OTA finds that improved access to these databases is needed at regional and field offices, a key consideration for future FAA information systems and enhancements currently being developed.

The advent of airline deregulation raised concerns that economic pressures could force airline managements to cut back on safety practices. The Office of Flight Standards, responsible for periodically inspecting all airlines to ensure regulatory compliance, is the logical choice for resolving this issue, but needs to collect and retain the necessary data. **Consistent, centralized records on the number, extent, and results of air carrier inspections are vital to ensuring the efficacy of FAA's safety function.**

Four data areas (all used to varying degrees throughout FAA) could provide warning signals for directing FAA attention, and with further refinement, could allow quantified estimates of changes in risk. They include:

- aicraft mechanical reliability, including unscheduled landings due to mechanical problems;
- airline operating practices, including aircraft scheduling and flightcrew work and duty shifts;
- inspection results, including quality assessments of airline practices and violation rates; and
- financial condition of airlines, and how that relates to any of the other safety indicators.

Airlines themselves keep crucial safety information and FAA could benefit from working more closely with airline data. For example, many air carriers maintain large internal databases that could be used to validate FAA databases. However, ensuring the confidentiality of the air carrier data is critical. FAA could encourage improved air carrier reporting of sensitive safety data, such as incidents, by guaranteeing that no penalties will resuit from reported information and could consider making nonreporting a violation. Additionally, access to airline computer systems, such as maintenance management systems,[37] could enhance FAA's monitoring capabilities.

While airlines share safety information through industry and government sponsored workshops, committees, and forums, no formal, centralized industry process is in place for collecting and evaluating these data. The airlines, as a group, might consider developing a data system to serve as a cooperative industry clearinghouse for safety-related maintenance, training, and operating information. The system could be established independently or in conduction with FAA, and ideally would tap the potential of the airlines' extensive automated information systems.

OTA concludes that all current FAA data systerns could benefit from a thorough, coordinated, agency-wide review, although enough shortcomings are known now to effect significant improvements in the system. Data managers, analysts, and field personnel should be involved collectively in all new data system development projects.

[37] One major airline recently provided the Federal Aviation Administration direct access to its computerized maintenance records.

Furthermore, OTA finds that an agency-wide, system safety management approach for data responsibility is needed, and that immediate coordination of Aviation Standards, Air Traffic, and the Aviation Safety Office efforts could bring major benefits providing support of policy development and planning, and permitting more focused allocation of agency resources. The current fragmented approach creates inconsistencies, nonstandardization, poor quality control, incompatible electronic systems, and insufficient data and data analyses. In the long term, FAA could establish a consistent monitoring and analysis program to refine the selection of safety indicators and the procedures for collecting and processing information. Safety management, including data managing, is an iterative process.