Chapter 1

Summary

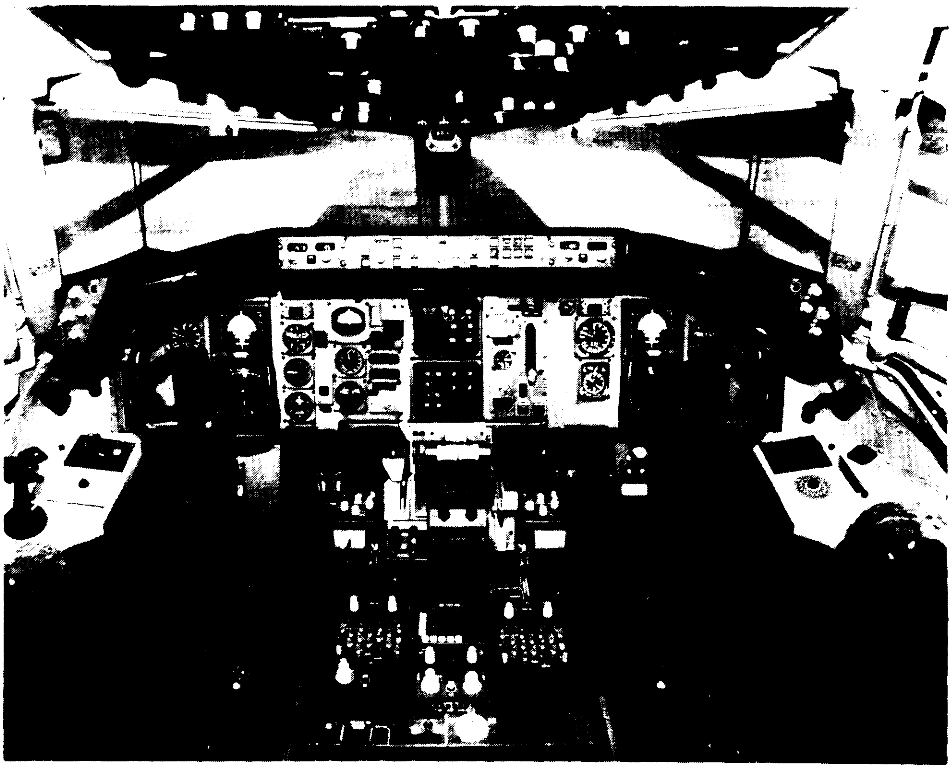

Photo credit: The Singer Co.

Advanced technology cockpits are important to the aviation safety system.

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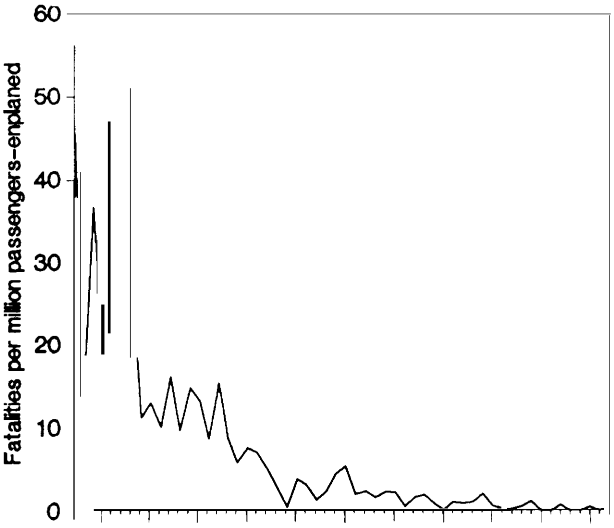
Chapter 1
Summary

Americans are a people both fascinated and frightened by flying. Thousands of U.S. citizens travel safely by air daily; air travelers numbered some 480 million in 1987, and lured by lower fares, passenger ranks have swelled by some 10 percent annually over the past 3 years. Yet no story about air travel seems too unimportant for media attention. Almost daily, newspaper stories chronicle the latest near midair collision (NMAC) or on-time and passenger complaint records. How well founded is the fear and how much of it is an outgrowth of the awe with which humans naturally view the marvel that flight represents?

Thanks to sustained and collective effort, the United States has achieved an aviation safety record that has continued to improve over time (see figure 1-1) and now ranks among the best in the world. Indeed, major passenger aircraft crashes are so infrequent that identifying aspects of the safety system that need modification requires thorough and wide-ranging research.

Figure 1-1.— Passenger Fatality Rates for Part 121 Scheduled Airlines[a]



[a]Part 121 scheduled airlines transport over 90 percent of commercial aviation passengers.

SOURCE: Office of Technology Assessment based on data compiled from the Civil Aeronautics Board, Federal Aviation Administration, and National Transportation Safety Board

Countless, interrelated, and overlapping supports form the safety system for commercial aviation in the United States. Participants include the Federal Aviation Administration (FAA); the U.S. Department of Transportation (DOT); the airlines and related labor groups; the aircraft and equipment manufacturers; and the public's elected representatives— the U.S. Congress. Numerous other groups, including the National Transportation Safety Board (NTSB), the National Aeronautics and Space Administration (NASA), the National Weather Service, and a variety of consumer and industry safety advocates, also play important roles. Together, these groups form an aviation safety system that is exceedingly complex and effective-only a few hundred of the 2 million deaths in the United States annually are from commercial aviation accidents, a marked contrast to the tens of thousands of annual motor vehicle accident fatalities.

Pivotal members of this safety network, the airlines, each follow individual corporate philosophies, but have one common characteristic–during the past decade each has changed operating practices to control costs, eliminating some of the layers of the old safety system and replacing them with alternatives that must still be evaluated. While "safety comes first" is the instant response of airline executives when asked the basis for management decisions, this universal answer masks wide variances in airline corporate cultures and operating procedures. Safety first means one set of corporate guidelines to the airline that already owns adequate landing slots at a crowded airport and has ample financial reserves to purchase additional slots. It means something else entirely to a financially strapped airline that must choose between discretionary maintenance of its aircraft and purchase of additional airport slots, because it cannot afford both. These alternatives illustrate that each airline uses different parameters to make the choices necessary to satisfy customers with reliable, low-fare service and still make a profit in a fiercely competitive industry.[1]

[1]Information in this report on changes in the industry is drawn directly from OTA'S primary research, including workshops, site visits, and conversations and correspondence with representatives of industry and the research community.

Media and congressional examination of passenger delays, on-time departures, and airline labor and maintenance practices are symptoms of the profound and rapid changes industry has undergone. Similar scrutiny of air traffic controller and inspector work force levels, tensions between DOT and FAA, and progress of the National Airspace System[2] AS) Plan are byproducts of national budget constraints, which have left FAA scrambling vainly to catch up with industry. Even after trouble spots have been pinpointed, Federal processes to put in place regulations, technologies, or programs as countermeasures are excessively time-consuming. Major changes in regulations, such as requirements for ground proximity warning systems or collision avoidance devices, usually occur only in the shocked and saddened aftermath of a major airline accident, even though the underlying causal problems were recognized years earlier.

[2]The National Airspace System Plan is a loose grouping of long-term technology improvements for the Federal Government's operations of the airways and air traffic control. Components include (among others) the Advanced Automation System for air traffic, Doppler weather radar, and the Microwave Landing System.

EVALUATING SAFETY IN TIMES OF CHANGE

Before passage of the Airline Deregulation Act (ADA) in 1978, the commercial airline industry was relatively stable. Industry changes occurred slowly, a constant group of carriers competed for the travel dollar, and the costs of required safety improvements could be passed quickly to the consumer. ADA removed Federal controls over routes, fares, and new entries to encourage competition, but left unaltered FAA's responsibility for commercial aviation safety. Events of the past decade have shown that neither Congress nor the executive branch fully comprehended the complexity of overseeing and regulating a newly competitive industry.

To determine how changes in airline operations after deregulation affected air safety and what steps the Federal Government could take to ensure safe skies for tomorrow, OTA took a comprehensive look at the entire commercial air safety system. The first step included a review of FAA safety operations and program areas, including technology development and training. This was followed by review and analysis of safety-related data from all available government and industry sources. The final component was identifying and assessing the changes in industry practices that have occurred over the past decade in the wake of economic deregulation. Financial data from the large and small airlines and information from the industry, collected on a confidential basis by OTA, were the major resources tapped.

Aggregate accident data show that the number of accidents for large airlines has held steady and has declined slightly for small airlines in the decade since deregulation (see table 1-1). However, growth in commercial air travel and the dominance of hub and spoke operations have changed airline and air traffic operations, in some cases dramatically. Vigorous Federal safety management programs and technical and operational oversight are vital to ensuring a high level of public safety, especially in a period of major upheaval. FAA, hard hit by budget cuts and personnel reductions, has fallen behind in both numbers of staff and levels of technical expertise.

OTA identified two key areas for enhancing air safety:

- safety management improvements, including streamlining FAA's internal organization, increasing inspector and operating work forces, raising levels of expertise, and establishing the primacy of FAA's safety responsibilities to ensure a more powerful system safety program; and
- system operating improvements, including expanding air traffic control (ATC) capacity and capability; enhancing human performance; and upgrading weather forecasting, detection, and dissemination and air/ground communications.

Table 1-1 .—Commercial Aviation Accident and Fatality Rates

Year	Part 121 (scheduled)	Part 121 (nonscheduled)	Part 135[a] (scheduled)	Part 135[b] (nonscheduled)
Accidents per million departures:				
75-77	4.8	53	27	58
78-80	3.7	39	27	54
81-83	4.1	18	12	55
84-86	2.8	22	8	53
87	4.3	23	14	38
75-87	3.8	30	17	54
Fatal accidents per million departures:				
75-77	***0.48***	***10.6***	***6.3***	11
78-80	0.57	6.5	6.5	13
81-83	0.72	2.6	2.6	13
84-86	0.34	8.0	2.1	11
87	0.43	4.6	4.1	12
75-87	0.51	6.5	4.1	12
Fatalities per million passengers-enplaned:[c]				
75-77	***0.34***	***24.2***	***3.4***	***14***
78-80	***0.56***	0.2	4.4	13
81-83	0.26	0.1	1.5	11
84-86	0.17	14.7	1.6	9
87	0.41	0.1	2.8	10
75-87	0.33	9.1	2.6	12

[a]Scheduled Part 135 passenger counts estimated by OTA based on Regional Airline Association data.
[b]Nonscheduled Part 135 passenger and departure data estimated by OTA based on National Air Transportation Association and other air taxi data.
[c]OTA calculations based on National Transportation Safety Board and Federal Aviation Administration data. All 1987 rates based unestimated passenger-enplanement data.

SOURCE: Office of Technology Assessment based on National Transportation Safety Board data as of January 198S, unless otherwise noted.

SAFETY MANAGEMENT

FAA has a dual mandate: “. . . to promote safety of flight . . . in air commerce through standard setting . . .“ and to carry out for the Secretary of Transportation the responsibility “. . . to encourage and foster the development of air commerce.”[3] While these tasks are not necessarily incompatible, an inherent tension exists between them in two vital safety activities of FAA—inspections, and managing and operating ATC. In times of massive change and rapid travel growth, such as the past decade, fulfilling both goals of the mandate presents the agency with unavoidable conflicts. The pressures on the air traffic system of airline schedules bunched at peak hours provide one obvious example. OTA concludes that if Congress wishes safety to be preeminent in FAA’s mandate, it may wish to make that explicit.

OTA analysis indicates that many FAA safety functions need strengthening. Among the most important are raising inspection and air traffic personnel levels; near-term improvements to ATC to cope with increased traffic; analytic tools for managing airport and airspace demand; training programs for inspectors, controllers, and technicians; programs

Photo credit: Federal Aviation Administration

Heavy traffic places extra demands on air traffic control and the aviation safety system.

[3]Public Law 85-726.

and systems for tracking and analyzing safety data; and long-range system planning.

Furthermore, FAA could recognize system safety management as a specific goal and refocus existing programs accordingly. For example, new emphasis could be placed on systematic and regular monitoring of financial conditions and management changes at airlines, realistic life-cycle planning for costs and personnel for the NAS Plan, and vigorous programs in hazard and human factors analysis for new technologies. OTA concludes that additional, stable funding resources to support these functions and FAA policy and resource management, technical competence, and system safety oversight will be needed. A rough analysis of programs and funding needs may be found in box l-A.

Improvements will not be sufficient if made piecemeal, however, because the safety functions of FAA are so closely interrelated. OTA concludes that FAA's functions cannot be separated into regulatory and operating (ATC) components without diminishing the effectiveness of the entire system. Furthermore, without more emphasis on system safety at the very top, FAA agency-wide problems that have hampered the organization's capabilities are likely to continue. Moreover, FAA organizational problems have exacerbated the impacts on the agency of government-wide problems of inefficient Federal personnel and procurement requirements and national budget constraints and priorities.

Management changes are needed that increase and support long-range planning; technical capabilities; internal coordination, especially between research and development (R&D) activities and ongoing operations; even-handed application of regulations in inspections, enforcement, and certification across regions; and management information systems. Shortcomings in these activities are embedded in the FAA structure and operations and

Box 1-A.-Commercial Aviation Safety Policy Options

Policy option	Maintain current safety with increased demand	Increase safety	Approximate costs ($ millions) Fixed	Recurring
FAA management improvements:				
1. Make safety FAA's preeminent responsibility	X	X	<1	<1
2. Lengthen and stabilize term of Administrator	X	X	<1	<1
3. Streamline FAA organization	X		1	1
4. Increase inspector staffing	X	X	<1	60
5. Address personnel issues of relocation, technical expertise, and compensation +	X		5	40
6. Inprogramsairforg field and facility personnel	X		80	20
7. Improve data collection and analysis	X		1	5
System operating improvements:				
1. ATC Near-terments	X		200	2
2* Controller and technician staffing	X		<1	300
3* Managepaceairportnd; develop system capacity models	X		20	2
4. Undertake human factors research and incorporate into procedures and regulations	X	X	20	5
5. Enhance hazardous weather safety and communications	X	X	00	<1
Total			350-450	400-500

KEY: FAA = Federal Aviation Administration; < = less than; ATC = air traffic control.
NOTE: FAA 1988 Appropriation = $6.1 billion.
SOURCE: Office (#Technology Assessment, 1988.

affect air traffic operations, technology development, and safety standards programs alike.

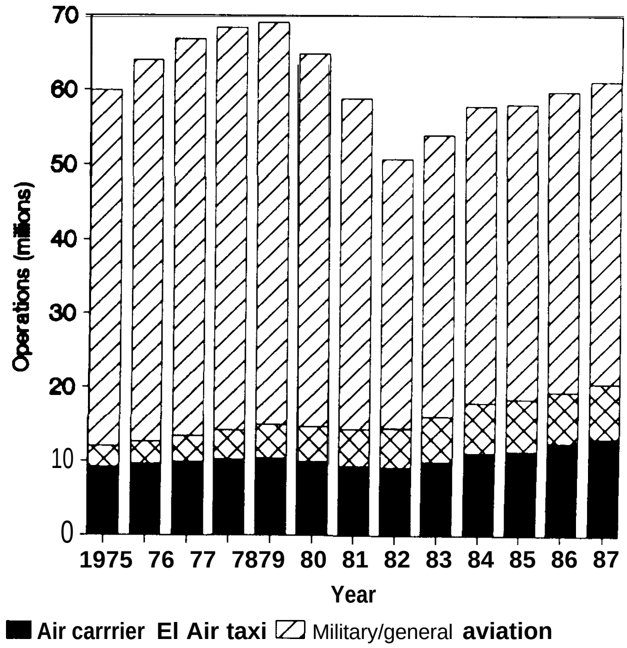
The most striking improvement in FAA operations and regulatory and oversight programs would result from the establishment of strong, independent, and consistent leadership by the FAA Administrator. Congress may wish to consider three far-reaching changes to bring about this goal:

- establishing the preeminence of the safety function in FAA's mandate, holding the Administrator accountable solely for safety, and allocating stable and adequate funding resources from the General Fund and the Air. port and Airway Trust Fund;
- streamlining the structure of FAA to give the Administrator direct control of the far-flung organization and to permit holding subordinates accountable for system safety; and
- increasing the Administrator's length of tenure to a fixed term, perhaps up to 5 years. To provide accountability, Congress may wish to require the Administrator to develop a rolling 5-year agency development plan and report annually on its status.

SYSTEM OPERATING IMPROVEMENTS

Commercial air transportation operations (take-offs and landings) at U.S. airports with FAA control towers have reached record levels each year since 1984, with commuters and air taxis accounting for one-third of those flights.[4] Due to declines in general aviation (GA) activity across the country, total traffic nationwide is still below the peak of 69 million operations reached in 1979 (see figure 1-2). Although GA and military flights generate a large volume of traffic nationwide, they represent only a fraction of the operations at the largest and busiest airports—less than 6 percent at Chicago O'Hare and Atlanta Hartsfield, for example. While GA (and some military aircraft) share the facilities, air carrier operations account for most increases in operations at major airports (see figure 1-3).

Figure 1-2.—Total Operations at Towered Airports



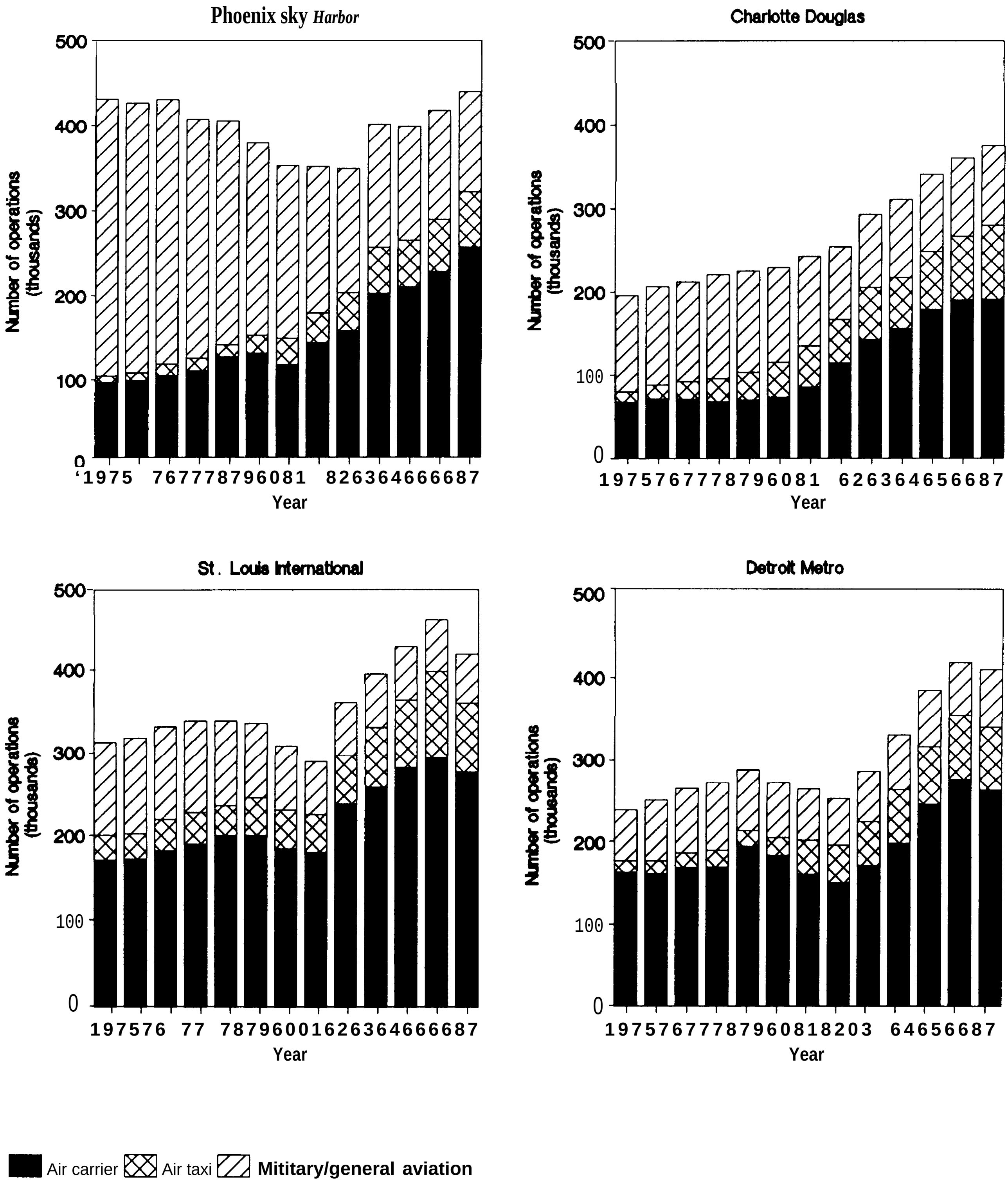
SOURCE: Office of Technology Assessment based on Federal Aviation Administration data.

The good news is that more people can afford to fly. But increased traffic does strain industry, airport, and ATC equipment and personnel, requiring them to perform consistently at peak ability—a requirement they are often ill-equipped to meet. Strains are visible in the form of travel delays at some airports even in good weather, due to air traffic and airport congestion-, equipment malfunction, and occasionally aircraft and ground crew shortages. Plans to build more runways and modernize airports have been stymied by interjurisdictional disputes over noise and land use that are unlikely to be resolved in the near term. ATC system renewal has moved at glacial speed, slowed by inadequate system planning, technology development difficulties, and administration and congressional budget de--cisions.

OTA found that increases in commercial air traffic correspond closely to the rise in reported NMACs

[4] Air traffic controllers, who record data on traffic operations, do not differentiate commuters from air taxis or Part 121 commuters from Part 135 commuters. Additionally, since many air taxis are similar to general aviation aircraft, an air taxi operation probably will not be counted as such unless it is so Indicated in the flight plan. Therefore, air taxi operations are most likely underestimated by these statistics.

Figure 1-3.—Air Traffic Activity at Selected Hubs

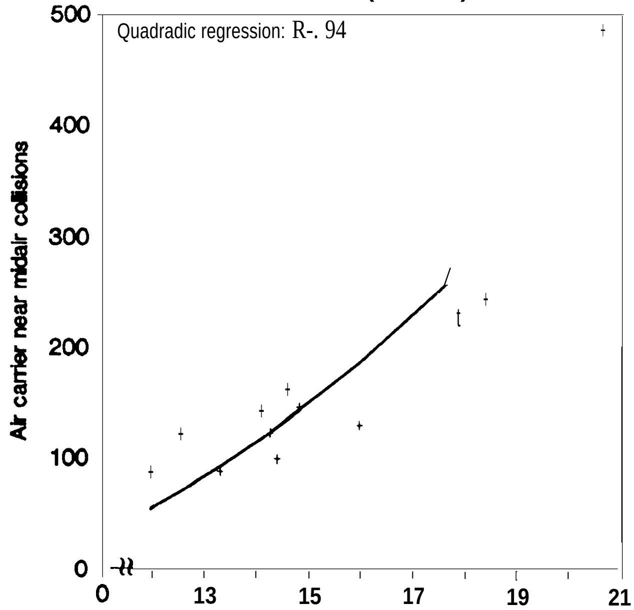


SOURCE: Office of Technology Assessment based on Federal Aviation Administration data.

Photo credit: Federal Aviation Administration

While they share the airspace with commercial airlines, general aviation planes make up only a fraction of the flights at the Nation's busiest airports.

Figure 104.—Air Carrier Near Midair Collisions (1975.87)



SOURCE: Office of Technology Assessment based on Federal Aviation Administration data.

involving commercial aircraft (see figure 1-4). While air traffic-related accidents are quite rare, and midair collisions show no trends, rising NMAC reports suggest that future growth in commercial traffic is a cause for concern. OTA concludes that continued vigorous air traffic growth and increased traffic densities at more airports could outstrip the capabilities of the traffic system. Without immediate steps to modernize the ATC system and to manage air traffic flow and demand as necessary, present safety levels may not be sustainable.

However, decisions about managing demand have major economic consequences for airlines—spelling success or failure for some small commuter airlines or large airlines in precarious financial condition. Such decisions thus pose serious equity issues and require careful scrutiny, public debate, and cooperative, deliberate decisionmaking backed by sound technical analysis.

Accidents usually result from a combination of failures occurring sequentially, or on occasion, simultaneously in one or more activities (see figure 1-5). Commercial flight safety requires that many varied activities be carried out without major error. Human error, severe weather, aircraft component failure, and limitations of the air traffic environment are the four primary causal factors in aviation accidents (see table 1-2).

OTA analyses of data from FAA, NTSB, airlines, and aircraft manufacturers confirmed that human error is at least partially responsible for over 65 percent of accidents, a percentage that has held constant over the past decade (see figure 1-6). Moreover, aircraft component failures, factors in over 40 percent of all accidents, are often compounded by human error, and weather-related accidents often involve faulty decisionmaking or communication.

OTA concludes that long-term improvements in aviation safety will come primarily from human-factors solutions, and that such solutions will be found through consistent, long-term support for R&D, analysis, and applications. Moreover, current FAA programs to understand human error and enhance controller, mechanic, and cockpit crew performance are inadequate. Data on reliability of human performance are difficult to collect, however, and causes of human error are not fully understood. The traffic environment, aircraft design, and management practices directly influence human performance, and recent changes in aircraft technology and operating practices have widespread implications that require extensive research. Human-factors hazard analyses, such as studies to determine whether people can operate new technologies quick-

Table 1-2.—Part 121 Accident Causes

	Fatal accidents (1975-86)	Fatal accidents (by percent[a])	Total accidents (1982-85)	Total accidents (by percent[a])
Initiating causal factor:				
Pilot	15	43	23	46
Personnel	5[b]	14	4[c]	8
Aircraft	9	26	18	36
Weather	3	9	2	4
Miscellaneous	3d	9	3[e]	6
All causal factors:[f]				
Pilot	20	57	27	54
Personnel	5	14	4	8
Aircraft	12	34	23	46
Weather	9	26	11	22
Miscellaneous	3	9	3	6
Total accidents	35		50	

NOTE: Accidents involving weather turbulence, sabotage, or nonoperational events, such as ramp activities, are not included.
[a]Initiating causal factors may not total 100 percent due to rounding. For all causal factors, numbers do not total 100 percent, because most accidents involve multiple causes.
[b]Three accidents involving air traffic control personnel, one involving maintenance personnel, and one involving the pilot of another aircraft.
[c]Two accidents involving air traffic control personnel and two involving maintenance personnel.
[d]Two midair collisions, including Aeromexico DC-9/PA 2&181 over Cerritos, CA on Aug. 31, 1986, and one in-flight collision with a parachutist.
[e]Two collisions with birds and one collision while taxiing.
[f]All causal factors includes up t. two significant causes in the sequence of events leading to the accident.

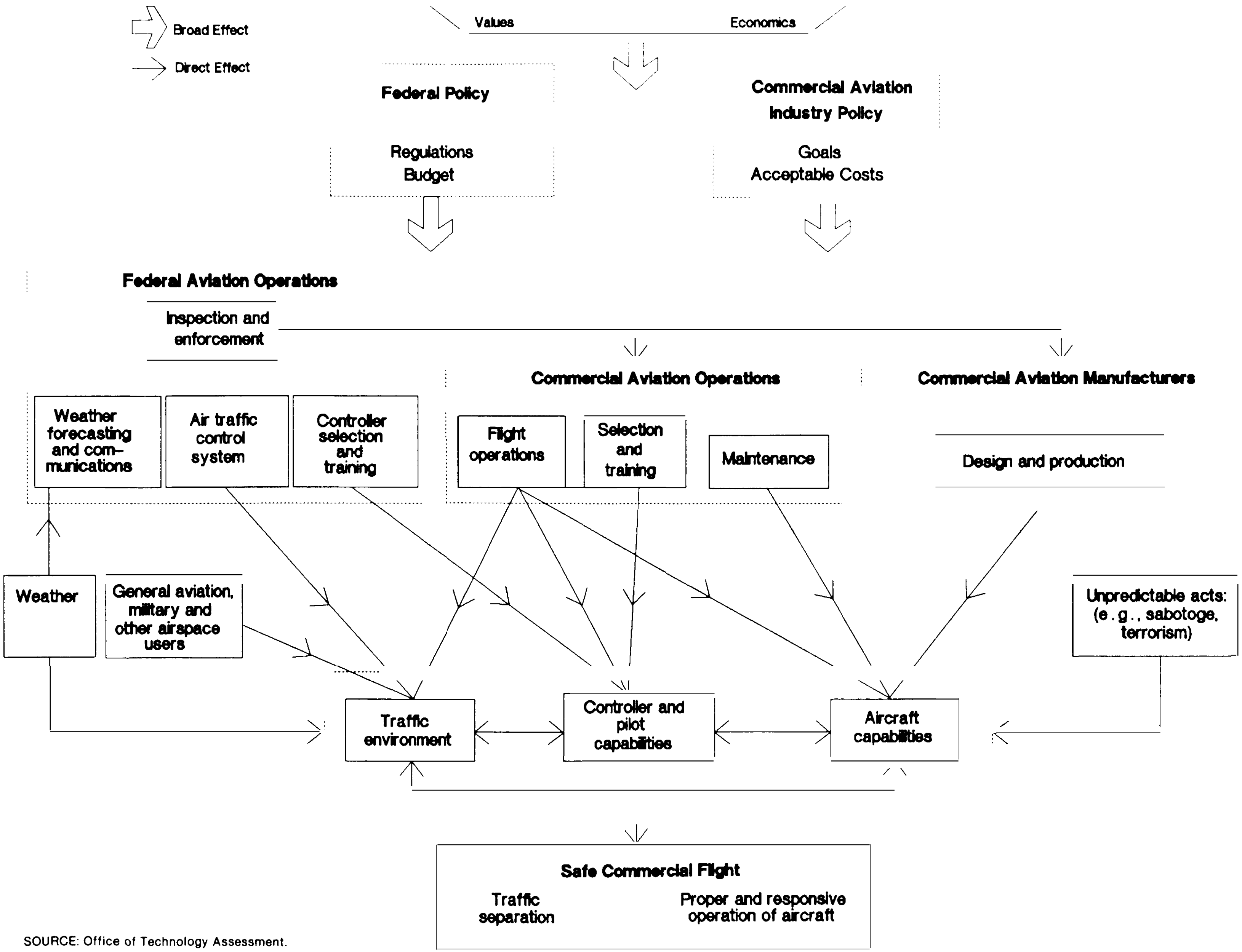
SOURCE: Office of Technology Assessment based on National Transportation Safety Board data as of January 1988.

ly and accurately in an emergency, are not presently a normal part of aircraft or ATC system design or certification. Such studies are vitally important as future technologies are introduced. Automation, pilot and controller selection and training, and the effects of management practices are specifically in need of attention.

In the short term, existing resources and understanding of human factors at NASA, the Department of Defense, universities, and industry could be utilized. FAA could request assistance from these groups to provide guidance for developing and disseminating explicit training procedures for upgrading crew coordination and decisionmaking. In the longer term, Congress may wish to consider making human factors a core research technology and direct FAA to designate management resources for a research program. An FAA program that utilizes available human-factors expertise at NASA and other organizations to carry out fundamental work in this area could bring improvements to safety without large expenditures of additional funds.

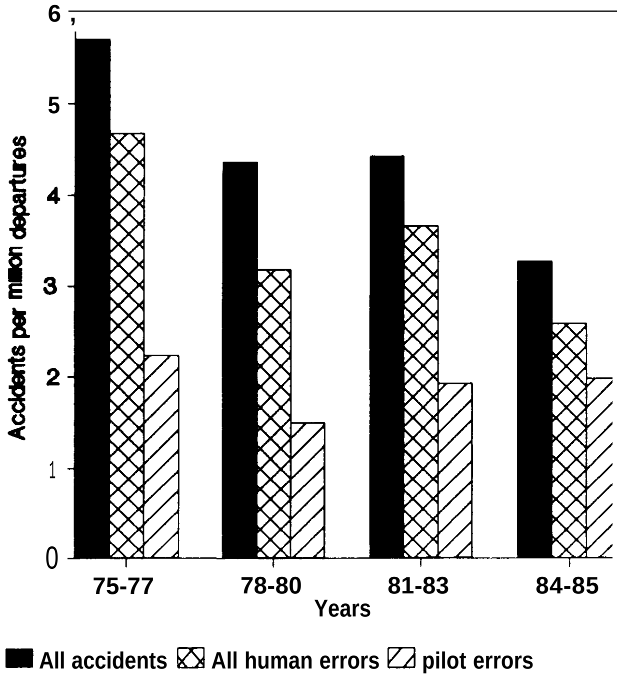
While technological progress has contributed greatly to advances in air safety, further improvements through technology will come at relatively higher cost. Nonetheless, OTA concludes that technologies to improve prediction, detection, and interpretation of severe weather and for communicating and coordinating this information between ATC and the cockpit could contribute substantially to greater safety. In particular, FAA commitment to rapid integration of modern, digital air/ground communications, augmented by appropriate automation, could increase both safety and efficiency.

Figure 1-5.—Accident Cause and Prevention Chain



SOURCE: Office of Technology Assessment.

Figure 1-6.– Part 121 Total and Human Error. Caused Accidents



SOURCE: Office of Technology Assessment based on National Transportation Safety Board data, 1975-85. Data from 1986 and 19S7 are not yet available.

CHANGES IN THE SAFETY SYSTEM: INDUSTRY

Commercial aviation includes flights by scheduled large jetliners, smaller commuter planes, and air taxis, as well as cargo and charter jet service. Each industry segment has substantially different safety and economic effects on the aviation system. For convenience, OTA will refer to airlines as major (large) or commuter (regional). In practice, however, the divisions under the regulations are far from being so simple (for details see box 3-A in ch. 3). The formal designations for these airlines are:

- Major or large—14 CFR Part 12 l—operations of aircraft with more than 30 seats or 7,500 payload-pounds. Part 121 airlines carried 95 percent of passengers and accounted for 99 percent of revenue passenger-miles in 1986.
- . Commuter—14 CFR Part 135—operations of aircraft with 30 seats or fewer. Part 135 commuter[5] airlines transported 4 percent of passengers, and air taxis accounted for only 1 percent.

Photo credit: Fokker Aircraft USA, Inc.

Some commuter airlines, such as this one, adhere to the same operating and airworthiness standards as large jetliners.

The single most significant change in large airline operations over the past decade has been the almost universal shift to hub-and-spoke operations that enable airlines to dominate their most successful markets. To retain connecting passengers, the major air-

[5]These definitions can be confusing; some portions of the Federal Code apply the terms "commuter" or "regional" to scheduled operations of aircraft with 60 seats or fewer. Accident statistics show that the largest commuter airlines are as safe as the major carriers.

lines have made arrangements with regional and commuter lines that feed passengers from small communities to their hubs to share identification codes on computerized reservations systems—a practice known as code--sharing. Where the performance of the commuter line is less than satisfactory, or where a chance exists that a head-to-head competitor at the hub may make a more favorable code-sharing arrangement, the major line is likely to buy the commuter outright. Of the 50 largest regional airlines that existed as independent entities several years ago, only 2 now remain unattached to a larger airline. Through hub dominance, the power of computerized reservation system booking, and code-sharing arrangements, the airline industry in 1988 is virtually closed to new entrants, except for carriers specializing in specific market niches.

However, competition for passengers remains keen and economic pressures on carriers are intense. OTA research indicates that while airline officials are concerned about safety, financial considerations drive many industry decisions and will continue to do so as long as strong competition exists among the airlines. Primary decisionmakers at today's airlines do not always have the same understanding of operations that permeates management decisions made by experienced officials dedicated to safety.

Many factors related to enlarging market share and hub scheduling have affected industry's struggle to modernize and restructure. OTA identified the following as particularly difficult problem areas.

- Lag time between airlines' restructuring to capture market share and commensurate changes in their safety procedures. Hub-and-spoke operations require tight turnaround schedules, leaving little time for minor maintenance tasks during the day. Such operations also require airlines either to arrange for adequate maintenance capability at the spoke ends of their operations or to fly the aircraft back to a maintenance facility at night for repair. Some airlines contract with other carriers that have crews and parts available at spoke points; some redeploy their own personnel. If flying an ailing aircraft back to a hub is not feasible, other carriers charter aircraft and fly parts and mechanics to remote sites when necessary.

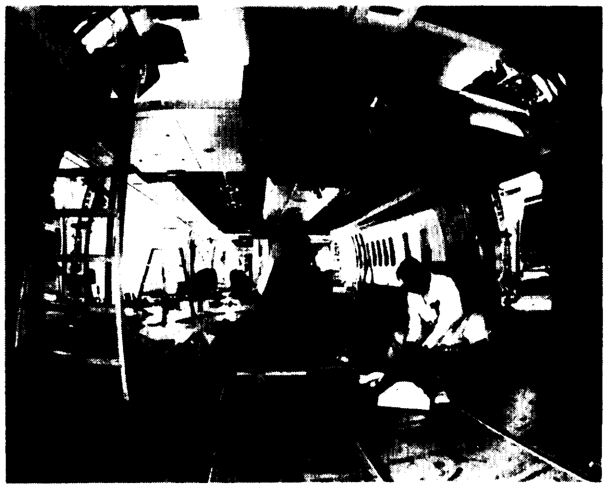


Photo credit: United Airlines

Careful attention to detail by airline maintenance personnel and Federal inspectors is essential to ensure system safety.

- As airlines merge or expand rapidly, they acquire or purchase used equipment, often aircraft different from those in their existing fleet. Some airlines choose to contract maintenance for planes that differ from the majority in their fleets. For other companies, repositioning and retraining maintenance personnel and rearranging equipment and inventory takes time and planning. Few airlines understood ahead of time how much care and advance planning would be required for these changes in their ground operations.
- Every airline has made differing and substantial structural changes to improve economic efficiency, although each company vigorously denies compromising safety by the alterations it has made. To lower costs some airlines have reduced planning and engineering departments, while others have pared back safety departments. Others eliminated weather or meteorology sections or began to make discretionary maintenance spending decisions based on the tightness of the budget. So long as airlines comply with minimum Federal standards, FAA has no grounds for questioning these types of decisions.
- Mergers have caused substantial industry readjustments; in some cases, flight crews have had to learn entirely new procedures. FAA does not

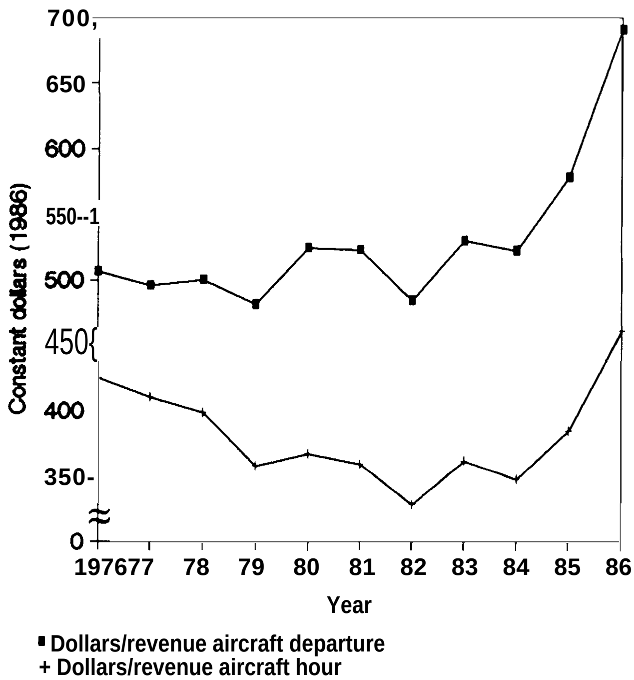
have human factors expertise to monitor or predict the impact of such changes on pilot performance, and Federal regulations are silent on methods to assist airline personnel through the difficulties inherent in a merger. Finally, while many small commuter airlines remain independent, numerous regional airlines now operate as adjuncts to major carriers. Only a few of the major airlines have taken steps to bolster the safety of their commuter lines by assisting with pilot and mechanic training.

- Many airlines have hired large numbers of flight and maintenance personnel to meet shortages caused by retirements and increases in air travel. While larger airlines have been able to keep experience levels high by hiring recently retired military pilots or pilots from smaller airlines, commuter airlines find themselves used as training grounds for larger carriers, which offer higher salaries and opportunities to fly jet aircraft. Several commuter carriers told OTA that they are experiencing over 100 percent turnover annually in their pilot ranks. Training facilities and programs are stretched, and experience levels in some of the major airlines and many of the regional and commuter lines have declined. Many regional airlines must hire pilots with little or no jet experience and limited flying hours (see table 1-3).

Airline management practices are an important control valve for commercial aviation safety, and airlines have always had different approaches to managing their operations. For example, while some airlines are reducing or eliminating safety, weather, or medical departments, other airlines with excellent safety records have never had such departments, preferring other safety management approaches. Some airlines are leasing aircraft and contracting maintenance, finding these procedures to be cost-effective. Moreover, OTA analysis showed increased spending for maintenance (in constant dollars) across the industry (see figure 1-7) during the past 5 years and no deterioration in aircraft reliability. (See figure 1-8 for an example.)

OTA finds that many airlines have lowered hire ing standards, increased pilot and mechanic duty time, shifted to leased aircraft, and reorganized and cut wages. However, the cumulative impacts on safety of these decisions are difficult to quantify. Compensating activities in other parts of the system may counterbalance safety impacts of these actions. For example, FAA concentrated its oversight activities in the National Air Transportation

Figure 1.7.—Average Flight Equipment Maintenance Expense for B727-200 Fleet[a]



[a]Major carriers only.

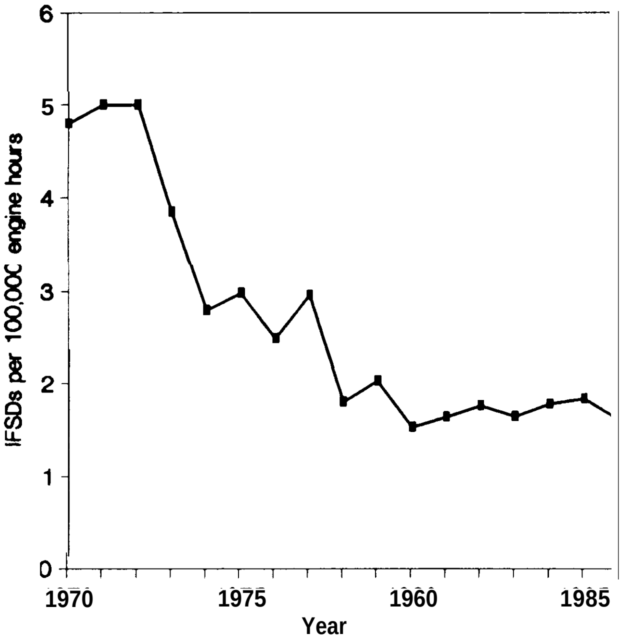
SOURCE: Office of Technology Assessment based on Research and Special Programs Administration data,

Table I-3.—Qualifications of New-Hire Commercial Flight Crews (percent, by year)

	Major airlines		National airlines		Other jet airlines		Regional airlines	
Pilots with	1983	1986	1983	1986	1983	1986	1983	1986
Less than 2,000 hours total flight time	1	13	0		14	12	9	29
No military experience	46	56	18	66	55	70	83	88
No jet or turboprop flight time	1	2	1	6	24	29	32	28
No air transport pilot certificate and no flight engineer certificate	18	26	24	41	42	56	77	76

SOURCE: Office of Technology Assessment based on Future Aviation Professionals of America data, as of May 1987.

Figure 1-8.—Basic In-flight Shutdown (IFSD) Rate, (domestic operators only) B727/JT8D Engines



SOURCE: Office of Technology Assessment based on Boeing Commercial Airplane Co. data.

Inspection program in 1984. The inspections showed that airlines undergoing management turmoil tend to overlook details of safety programs. Since 1984, FAA has monitored selected airlines as closely as possible, given the limited numbers of trained inspectors. Large fines have occasionally resulted from these FAA activities, and airlines have subsequently upgraded safety procedures and recordkeeping.[6]

[6]U.S. Department of Transportation, "National Air Transportation Inspection Program: Federal Aviation Administration, Mar. 4, 1984 - June 5, 1984," Report for the Secretary, unpublished typescript.

Some airlines have complained that FAA surveillance involves looking at a paper trail only, ignoring the fact that paper records are vital management tools as well as the major enforcement mechanism for FAA. Short aircraft turnaround times increase dependence on records; a 20-minute time period between pull up at the gate and departure leaves insufficient time for a thorough FAA inspection (not to mention repairs by mechanics). Under such circumstances, the aircraft logbook is an indispensable record of maintenance activities for airline personnel and FAA alike.

Limited Federal resources preclude frequent surprise inspections or indepth, continuous inspections, except on a special basis. OTA concludes that vigilant FAA oversight of airline management procedures through unannounced inspections and periodic indepth audits of every large and small airline are indispensable tools for ensuring public safety. Based on operating and marketing changes now underway, the commuter industry warrants extensive and intensive FAA oversight during the shakeout expected over the next few years. The special FAA inspection effort for commuters announced in early 1988 is a step in the right direction. However, it has forced postponement of several major carrier inspections, because FAA does not have enough inspectors to do both.

CHANGES IN THE SAFETY SYSTEM: FAA

Since Congress dismantled the Civil Aeronautics Board, FAA has been the chief regulator of the U.S. airline industry, with some political and analytic support from other parts of DOT. The task is formidable. On the one hand, the agency must stand up to intense pressure from DOT and industry on proposed regulatory and programmatic changes, and, on the other, address constant public and congressional anxieties about safety and convenience. Moreover, local governments play roles in determining airport operations and development that often conflict with FAA goals. Over the past several years, public attention has again focused sharply on whether FAA has the institutional capability and resources to carry out its operating, standard setting, rulemaking, and technology development functions effectively and guarantee compliance through its inspection programs.

Over the past decade, FAA's effectiveness has been undercut by administration policy decisions carried out by DOT and by national budget constraints entirely external to FAA activities. These have slowed FAA regulatory processes and procurement, limited the size of the inspection, ATC, and facilities technician work forces, eliminated many expert technical personnel who chose to seek more rewarding jobs in industry, and prevented modernization of equipment. Agency training programs, technical and human factors R&D, and long-range comprehensive planning have been especially hard hit.

Only an agency with strong leadership and singleness of purpose and responsibility could maintain a steady course under such opposing pressures, and at FAA, such pressures only magnify internal management and structural shortcomings. The agency's organization is extraordinarily decentralized, making turf battles inevitable among the 22 top managers reporting to the Administrator. Rapid turnover in Administrators, common in executive branch agencies, has made such internal disagreements especially destructive. For example, although policy nominally originates from FAA headquarters, FAA standards for certification are not uniformly interpreted across regions. In at least one instance—exit doors for the Boeing 747 aircraft—the responsible region's ruling was effectively overturned by the Administrator, who wrote to the airlines, asking them not to use the eight-door configuration approved by the region.

OTA finds that while the autonomy of the regions permits allocation of personnel according to regional need, policy guidance to FAA regions from headquarters is inadequate to ensure nationally consistent standards. Lack of strong top management, inadequate comprehensive planning, and diminished technical expertise have led on occasion to budget and regulatory priorities being set for FAA through pressure on Congress or DOT policy officials by potent and vocal special interest groups. Appropriate consideration of system safety is not always part of this process.

Despite these deficiencies in the organization, FAA staff members at all levels are dedicated to aviation and to their operational and technical missions. However, these characteristics do not always lend themselves to full appreciation for intergovernmental issues, such as local land use decisions, environmental problems associated with airport construction, or complaints about airline schedule reliability. **OTA** concludes that many decisions affecting aviation policy require participation by public officials at all governmental levels, ranging from Congress to local airport authorities. Such decisions cannot be made solely by FAA, an organization heavily reliant on technical and industry expertise.

FAA Planning and Air Traffic System Management

An essential support for system safety management is an agency-wide comprehensive planning capability that includes participation by all major FAA programs in setting long-term safety goals and budget priorities to achieve them. Coupled with firm, consistent, top-level guidance, an agency-wide plan could ease conflicts between and among Associate Administrators and Regional Office Directors. Lack of such planning capability has created substantial difficulties for ATC programs.

In the best of times, airport and ATC issues create tension for FAA between ensuring the maximum traffic flow desired by industry, meeting safety standards, and considering State or local environmental and land use concerns. In its 1988 reauthorization of the Airport and Airway Trust Fund, Congress reaffirmed the importance of environmental concerns by increasing funding to airport authorities for land purchases. Such concerns are serious obstacles to near-term airport construction or expansion; we may have to live with existing airports for some years.

The air traffic system has many individual, interdependent components, and each one affects the safety and capacity of the overall system. Significant components affecting capacity of the current air traffic system are:

- airports;
- air route structure;
- the ATC system, including hardware, software and the humans who operate the system; and
- communications.

Any increase or decrease in capacity in one part of the system (e.g., airports) requires adjustments to the other parts to stabilize overall system capacity.

FAA badly needs effective tools for evaluating airport and airspace capacity and devising methods for increasing system capacity. At present, for example, weather technologies are used by Central Flow Control to determine capacity for airports. Aircraft are held on the ground when the predicted demand on a destination airport exceeds its capacity, and system-wide delays often occur as a result.

However, while passengers understand delays due to bad weather, decisions about capacity in good weather are much more problematic. Current DOT methods of encouraging airlines to spread peak hour demand to avoid delays at busy airports consist basically of jawboning and persuasion. Failure of these techniques means massive inconvenience and public uproar, Yet devising and implementing equitable methods of managing demand pose difficult and sensitive policy questions for the government. Air and ground space management may require imposing surcharges or altering airline schedules and airport landing slots at the most congested facilities during peak hours—actions that directly affect airline profits and market share. OTA finds that technical expertise from FAA is essential to DOT and Congress in making difficult decisions on constrained airport and airspace capacity. Continued emphasis on developing analytic tools, including models, to help understand the capacity of the air traffic systern would provide FAA with vital technical knowledge to support difficult future decisions on capacity, safety, noise, and airline scheduling.

Air traffic equipment improvements, flight path restructuring, and well-trained operating and support personnel are important near-term safety improvements given existing and projected airport capacity constraints. Both realistic scheduling and a fully staffed and adequately equipped ATC system are required for the system to be able to handle safely continued growth in air travel without burdensome delays. FAA considers the new Host computers in en route centers to be adequate until the Advanced Automation System is available. However, these computers address only some of the current system problems. For example, computer and radar capabilities in the Terminal Radar Approach Control (TRACON) facilities are inadequate to handle the increased traffic load that will occur when broadened requirements for altitude encoding transponders in GA aircraft are implemented. (For further information, see chapter 7.) Currently, the New York TRACON equipment is being upgraded to handle increased demand. However, in late March 1988, FAA announced a request for fiscal year 1989 funds to upgrade equipment at other TRACONs. OTA finds that these equipment improvements should be completed as quickly as possible. They are essential to the successful implementation of broadened transponder and collision avoidance equipment requirements. Congressional support for funding will allow an important addition to systern safety to go forward.

Personnel and Training

FAA and DOT budget decisions in the early 1980s to reduce personnel levels created shortages of trained personnel in three critical areas (see table 1-4), and the safety system continues to feel the effects. For example, the ranks of trained operations and maintenance inspectors have become very thin, while airline operations have been changing rapidly and dramatically. Federal processes are so slow that FAA became adequately staffed to handle new industry entrants only in 1984, the year that new airlines began to go bankrupt or merge with established carriers. **OTA** concludes that FAA inspector, controller, and technician work force levels still do not meet system safety requirements.

DOT's budget request for fiscal year 1989 includes funds for about 2,500 inspectors. However, hiring

Table 1.4.–Selected FAA Employee Totals, 1978-87

Occupation	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
Air traffic controller[a]	16,750	16,853	16,584	6,658	11,416	11,946	11,944	12,245	12,429	12,847
Aviation safety inspector[b]	1,466	NIA	1,499	1,615	1,423	1,331	1,394	1,475	1,813	1,939
Electronics technician	9,423	9,209	8,871	8,432	8,031	7,633	7,229	6,856	6,600	6,740

[a]Full performance level and developmental controllers at towers and centers.
[b]Air carrier inspectors (approximately 40 percent of the total) were responsible for 145 air carriers, while general aviation inspectors were responsible fOr 173 pall 135 commuter airlines. 7,804 other commercial aircraft operators, and 5,210 aviation schools and repair stations as of Mar. 10, 1988.
communications, navigational aid, radar, and automation technicians.

SOURCE: Office of Technology Assessment based on Federal Aviation Administration data as follows: controller data as of September 1987; inspector data as of March 1988: and technician data as of March 1988.

an adequate number of inspectors is just the beginning. As aircraft technologies become more complex and sophisticated, training for aviation inspectors will become even more critical. While efforts at FAA headquarters to standardize inspection procedures and job descriptions are underway, they will not be completed for at least another year. FAA inspectors continue to operate according to the policies and on-the-job training of the particular field office in which they are located, leading to substantial inequities in enforcement. **OTA** concludes that immediate steps to speed standardization of inspection procedures and provide adequate recordkeeping for agency inspection information are priority needs. Project SAFE, FAA's program to accomplish these goals, is a move in the right direction, but progress is painfully slow.

Moreover, FAA headquarters, Aviation Standards field offices, and the FAA Academy need a coordinated long-term plan for number of students, curriculum, and training equipment. Frequently, Academy courses do not adequately prepare inspectors to take up their duties once they return to the regional offices. Regional offices, desperate to have adequately trained personnel to meet the needs of the airlines they supervise, provide independent training that varies from region to region, perpetuating the regional differences in application of supposedly national standards. At present, the Academy must react to unforeseeable short-term needs, rather than proceeding efficiently to improve its training capabilities.

The firing of striking air traffic controllers in 1981 is an example of a Federal decision made for national labor policy reasons but felt keenly by FAA. Hiring of new controllers lagged far behind the need, and a few aftereffects linger to this day. While some facilities have a plethora of new controllers, they cannot give them training and experience quickly and efficiently to relieve the full-performance level controllers or replace those who retire. Still other facilities, such as those in the New York City area, cannot attract new controllers because of the high cost of living. Federal policies do not permit cost of living differentials to be paid for employees assigned to high cost areas of the country.

Furthermore, air traffic controller training programs and equipment are outdated and badly in need of carefully planned and systematic overhaul. Air traffic controllers at some en route facilities now receive site-specific training at the FAA Academy in Oklahoma City because of inadequate resources at the en route facilities. OTA finds that improved simulation training for air traffic controllers is potentially more cost-effective than present programs.

As NAS becomes more fully automated, personnel who maintain NAS equipment will require more sophisticated training. Moreover, planning realistically for maintenance personnel needs early in the technology development process is important. Past reductions in facilities technician ranks have made maintaining aging ATC equipment difficult. Conditions at the FAA Academy are not conducive to attracting first-rate instructors to train a new generation of airway facilities maintenance personnel, and maintenance training is an afterthought in the technology development process.

OTA concludes that support and funding from FAA headquarters for immediate and long-term programs to upgrade inspector, controller, and technician training are vital to ensure a trained work force capable of handling future system safety needs. Congress may wish to consider legislation to permit hiring of retired personnel to maintain sufficient levels of expertise. Furthermore, Congress may wish to encourage FAA to raise the grade levels of instructors at the Academy and institute policies to allow easier movement between the field and the Academy.

Technological advances and changes in the aviation industry bring new aircraft technologies that are beyond FAA expertise for ensuring adequate safety standards. Furthermore, aircraft maintenance procedures have changed substantially, and FAA does not have adequate numbers of expert technical personnel or training capabilities for new staff, nor does it have funding available to attract them from industry. FAA programs such as Project SMART[7] and National Resource Specialists are steps to address this issue, but FAA must rely on competence and professionalism in the manufacturing and operating industries to ensure airworthiness of commercial aircraft. The future will continue to bring new and increasingly sophisticated commercial aviation technologies, many of which will be

[7]Project SMART is a plan to upgrade the Federal Aviation Administration's aircraft certification regulatory program.

introduced not for the sake of safety, but for the economic benefits they promise. Nonetheless, if introduced in the proper way, many hold the potential for decreasing the risk of an accident. OTA finds that, in the long term, FAA will need greater expertise on its staff in areas of new aviation technology to provide oversight comparable to today's. Congress may wish to consider making funding available specifically to bolster FAA's expert technical staff.

TECHNOLOGIES TO ENHANCE SAFETY

Historically, technological advances have contributed greatly to increasing safety. While further safety advancements through technology will be relatively costly, OTA concluded that several technology areas show real promise for improving safety, even as demands increase on the air system.

Severe weather is a contributing factor in many aircraft accidents, and the most common types of fatal weather accidents involve either windshear near the ground or icing prior to takeoff. Sensors such as Terminal Doppler Weather Radar (TDWR) hold potential for rapid detection of dangerous windshear. However, TDWR's great expense suggests that other, less expensive technologies could be examined for use at smaller airports to augment the enhanced Low Level Windshear Alert System. In addition, OTA concludes that training programs for pilots in recognizing and coping with severe weather, such as windshear, could be required for all commercial pilots. An R&D program in cooperation with industry to improve icing detection and de-icing of aircraft before takeoff and an improved cockpit crew training program for winter flying are other priorities.

Furthermore, current air/ground communications are not adequate in some cases to support pilot needs for both real-time ATC and real-time weather information. Providing ATC information to ensure separation between aircraft in the air and alert aircraft flying too low to the ground is the controllers' first priority. At times controllers are too busy to transmit weather information to pilots or are distracted from transmitting information by more urgent demands to separate traffic. Pilots need better weather information in the cockpit, and programs to develop message formats and workable air/ground communications for weather information are important immediate safety needs. OTA finds that rapid development and operational testing of alternative approaches to air/ground communication of weather information in parallel with weather sensor development would improve safety. For the longer term, digital air/ground data links with an appropriate level of automation can remove controllers from the process of relaying weather information to pilots, thus reducing controller workload. However, the human factors issues related to automated, digital communications for both controllers and pilots are not well understood. OTA concludes that R&D efforts on data link services, human factors, and system integration have a potentially high payoff for efficiency as well as safety.

Midair collisions account for about 5 percent of all fatal accidents involving airlines and about 10 percent of fatalities. The Traffic Alert/Collision Avoidance System (TCAS), the technology chosen by FAA for backing up the ATC system in collision avoidance, will help to eliminate these accidents. TCAS warns pilots only of nearby aircraft with operating transponders. Recent legislation requiring transponders for aircraft operating in terminal airspace where radar service is provided will enhance TCAS effectiveness in preventing collisions. TCAS has taken years to reach readiness for operational testing, due to the time required for technology development, testing, and certification. Because TCAS-II, required for commercial airlines in recent legislation, advises the pilot of vertical maneuvers only, efforts are underway to prepare TCAS-III, which suggests both horizontal and vertical maneuvers. Yet unknown are human factors and ATC issues that may be associated with widespread use of TCAS, although none of these issues appears to be a crucial stumbling block to TCAS implementation.

Although the United States has had few fatalities from collisions on the airport surface, a number of nonfatal collisions and close calls have occurred. As air traffic levels climb, the probability of a disastrous ground collision may increase unless compensatory steps are taken. OTA finds that ground safety could be improved by more uniform sign symbols on the airport surface, control lights at entrances to active runways, and procedural and training programs for pilots and controllers on ground safety. Surface detection radar upgrades, such as FAA's planned ASDE-3 radar, which presents ground traffic information to controllers, are important safeguards against ground collisions at larger airports. These radars can be enhanced to provide conflict alert to controllers and can eventually be integrated with digital air/ground communications to provide alerts directly to pilots. Congress may also wish to require exploration of low-cost programs such as signs and lights. Eventually, advanced display and communications systems and new types of sensors may also improve ground safety.

For the long term, although a program is underway to automate ATC through the Advanced Automation System, serious questions remain regarding the degree to which the goals of this program will be met, as well as about the human factors aspects of automation. Further examination of the potential hazards and efficiency gains resuiting from automation of controller functions could clarify whether the Advanced Automation System will meet its goal of safe control of higher traffic levels. OTA concludes that such research is a priority for FAA attention.

R&D Management

Schedule slippages and cost overruns in NAS Plan programs are not unusual for a government program of its size and technological complexity. However, FAA's management of technology development for the NAS Plan could be improved. More attention could be focused on rapid development of safety-critical NAS upgrades in areas such as air/ground communications and ATC facilities. For the longer term, more emphasis is needed on life-cycle planning to include adequate time for system development and testing to meet the ultimate goal of the NAS Plan: to provide the means for NAS users—pilots and passengers—to fly safely and efficiently. Internal FAA coordination and management incentives need to be clearly tied to this goal.

Recognizing that important near-term needs exist, FAA has established an interim support program for NAS. However, FAA has done relatively little near-term or longer-term research to support NAS developments. The new operations research and analysis effort known as the NAS Performance Analysis Capability deserves continued support. Such efforts can help FAA identify emerging ATC problems and parameters for solutions to the problems. Prototyping and test bed technologies to help evaluate technological and operational alternatives are important to investigate more fully ways that encourage innovation and timely fielding of technology.

FAA SAFETY DATA PROGRAMS

Commercial aviation accidents are such rare events that statistically valid trends often require at least 5 or more years of data. Accident data thus have limited value over short periods of time or for forecasting trends, and OTA concludes that the immediate effects of policy decisions cannot be monitored by short-term accident data. For example, the consequences of recent requirements for collision avoidance and transponder equipment will not appear in the accident data for many years.

Nonaccident data, however, can be used for short-term safety analyses, and FAA programs collect or have available to them a great deal of data for monitoring and assessing safety. However, while three separate FAA divisions have safety data responsibilities, databases, data terminology, and automated systems are often incompatible. Additionally, the agency uses most of its databases for recordkeeping and not for analysis and does not adequately emphasize accuracy or consistency, OTA concludes.

The few FAA studies that use nonaccident data appropriately have come from the Office of Aviation Safety, and for the most part address such FAA concerns as near midair collisions and air traffic controller errors. Four data areas—aircraft mechanical reliability, airline operating practices, inspection results, and the financial condition of airlines—contain helpful information for analysis. However, the effects on safety of airline practices, or changes in them, are rarely addressed in FAA studies, although FAA principal inspectors have a good understanding of their respective air carriers' safety approaches. A program to consolidate and communicate the knowledge through consistent, centralized records on the number, extent, or results of air carrier inspections could enhance safety. OTA finds that automating inspector recordkeeping and allocating resources to ensure that the system, including training, meets the needs of the field offices are important priorities for the Office of Aviation Standards.

Airlines themselves keep vital safety information, and FAA could benefit from working more closely with airline data, although ensuring the confidentiality of the air carrier data is crucial. FAA could encourage improved air carrier reporting of sensitive safety data, such as incidents, by guaranteeing that no penalties will result from reported information and by making nonreporting a violation. Additionally, access to airline computer systems, such as maintenance management systems, could enhance FAA's monitoring capabilities. One major airline already provides FAA with on-line access to its computerized maintenance database.

OTA finds that across FAA the management structure for data responsibility needs review, and that coordination of efforts by the Offices of Aviation Standards, Air Traffic, and Aviation Safety could promote a system safety approach. The data systems themselves could be significantly improved and coordinated with active participation by data managers, analysts, and field personnel in all three sections. OTA concluded that system safety would benefit if the Office of Aviation Safety played a coordinating and supporting role to Air Traffic and Aviation Standards efforts, rather than continuing its present emphasis on investigation and oversight.

Incorporating human factors needs into planning and procurement is an important component of system safety management. Historically, aviation accidents have declined after major technology advances, prompting reliance on technological solutions for safety problems. However, regulations governing training programs for cockpit crews are 20 years old and do not include changes appropriate to some advanced technologies. At present, numerous and substantial changes to airline training programs are covered by exemptions to Federal Aviation Regulations, granted on a case-by-case basis with little analytical support. OTA finds that FAA's regulatory program has not identified or addressed many training issues that are crucial to ensuring safety. Congress may wish to direct FAA to allocate resources and management personnel to develop guidelines and advisories for revising training standards and cockpit certification methods. Close coordination with ATC and controllers is imperative. Key areas for federally supported research or regulatory efforts include operational data collection, physiological and psychological factors, crew management, and optimal use of automation in the cockpit and in ATC facilities.