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Incident Data and Aviation Safety: Midair Collisions

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ABSTRACT

Aircraft accident and passenger fatality rates have generally improved throughout the post-deregulation period, but there is still concern that safety has recently deteriorated. Accident and fatality data are poorly suited for quick detection of changes in the underlying safety of the aviation system. Many have speculated that changes in the frequency of safety-related problems (incidents) may provide more sensitive measures of changing risk of aviation accidents. The usefulness of incident data hinges first on a correlation existing between incidents and accidents and, second, on the premise that careful tracking of changes in incidents may point to problems before they become apparent in accident data. This paper investigates the potential use of data on air traffic control operational errors, pilot deviations, and near midair collisions to provide insight into the risk of midair collision.

INTRODUCTION

The safety record of the airline industry in the U.S. has improved over the past decade. Both aircraft accident and passenger fatality rates have continued their historic downward trend throughout the post-deregulation period (Oster and Zorn). Although there is year-to-year variability, the rates at which passengers have been killed and seriously injured on both jet and commuter carriers and rates for both fatal and non-fatal accidents for jet carriers have improved between 1970 and 1987 (Table 1). During the post-deregulation period, 1979 to 1987, the various accident and fatality rates for both jet carriers and commuters were between 42 and 55 percent lower than during the 1970 to 1978 period. Even the PATCO strike in 1981, although it put considerable pressure on the air traffic control system, does not appear to have had an adverse impact on safety (Cunningham and Davis). Moreover, the improvement seems broadly based across both groups of jet carriers and individual carriers (Golaszewski and Bomberger). Despite the improvement of these rates, some still fear that safety has recently deteriorated. Accident and fatality rates are regarded, in this view, as measures of past safety with no predictive power; an accident is the final result of a failed safety system.

Aviation safety has evolved to rely on redundancy. The aviation system is designed to tolerate some electrical failure, mechanical failure, and human error in both aircraft operations and air traffic control without a resulting accident. When something breaks or malfunctions, a backup takes its place or a procedure is used to operate without it. Redundancy provides a "margin of safety" that allows failure of an individual component without disastrous consequences. Airline accidents have become rare events that are usually the result of several concurrent failures.

The redundancy approach complicates the assessment of changes in safety. While accidents and fatalities are the best long-run indicators of aviation safety, such data are poorly suited for quick detection of changes in the underlying safety of the system. An increased failure rate for primary systems and a resulting increased use of backup systems represents a decrease in the underlying safety of the system. Backup systems can also fail, so eventually an increased reliance on backup systems could lead to increased accidents and fatalities. Increased reliance on backup systems, however, may only increase the odds of an accident from one in three million to one in two million. Over the long run, the higher odds would eventually show up in a greater number of accidents, but it would take a great deal of time, and a great many accidents, to detect such a change in accident rates with confidence. Measures that provide more sensitive measures of changes in the underlying safety of the aviation system are needed—measures that can detect changes in the margin of safety. This paper investigates the potential use of data on several types of incidents associated with the risk of midair collision.

DEFINING THE MARGIN OF SAFETY

The margin of safety is commonly thought of as that extra cushion built into the aviation system that allows failures (or errors) in mechanical, human, or technological components to occur without a resulting accident. If the system becomes less tolerant of such failures or if such failures occur more frequently, the risk of accident increases and the margin of safety has eroded.

Conceptually, there are two different ways to think about the margin of safety: a threshold approach and a continuum approach. The threshold approach is best illustrated with the analogy of a bridge. In building a bridge, the design engineer will typically design for a greater load than is ever anticipated in normal use. This extra strength is a margin of safety for the bridge to allow for unanticipated loads, substandard materials, slight errors in construction, or deterioration of the materials over time. If the design engineer is overly cautious, the margin of safety in the bridge may be so great that a reduction in the unneeded strength may be possible without increasing the risk of using the bridge. In practice, there may be no greater safety

TABLE 1

**Airline Safety Rates
1970-1987**

Industry Segment	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987[1]
Fatalities per one million enplanements:																		
Jet Carriers	0.00	0.45	0.93	0.70	0.81	0.56	0.00	0.27	0.56	0.89	0.00	0.01	0.76	0.01	0.00	0.43	0.00	0.52
Commuters	4.45	5.96	2.28	0.88	3.07	1.52	0.51	0.33	1.63	2.79	1.62	1.23	0.05	0.32	1.45	0.70	0.11	0.63
Serious Injuries per one million enplanements:																		
Jet Carriers	0.05	0.18	0.68	0.13	0.13	0.18	0.45	0.11	0.28	0.04	0.02	0.05	0.05	0.03	0.02	0.05	0.03	0.11
Commuters	3.51	3.19	0.19	0.00	1.75	0.28	0.76	0.44	1.72	1.36	0.41	0.91	0.75	0.27	0.38	0.26	0.21	0.26
Fatal Accidents per one million departures:[2]																		
Jet Carriers	0.00	0.42	1.06	0.83	0.45	0.23	0.00	0.21	0.84	0.39	0.00	0.20	0.64	0.21	0.00	0.37	0.00	0.43
Serious Accidents per one million departures:[2]																		
Jet Carriers	1.67	1.92	2.33	1.04	2.71	2.48	1.96	0.85	1.26	0.78	0.78	0.60	0.64	1.28	0.58	0.55	1.34	1.29
Minor Accidents per one million departures:[2]																		
Jet Carriers	3.98	3.85	4.02	3.33	2.93	1.35	1.31	1.91	1.47	1.17	0.20	2.61	1.49	1.28	1.55	0.92	2.16	1.44

[1]1987 departure and enplanement data were estimated.
[2]Departure data are not available for commuters.
Source: Derived from computer printout of Part 121 and 135 operation accident briefs provided by the National Transportation Safety Board; Regional Airline Association, Annual Reports, various years; and Federal Aviation Administration *Traffic Data of Certified Route Air Carriers: Domestic Operations of the Passenger/Cargo Carriers.*

in a bridge that is five times as strong as necessary compared to one that is only four times as strong as necessary. At some point, however, the margin of safety could become so thin as to cause concern. A bridge built to accommodate only a one percent greater load than the maximum anticipated probably relies too heavily on the designer's ability to anticipate the loads to which the bridge will be subjected.

For a bridge, the margin of safety can be thought of as the extra strength that the designer never expects to need. For aviation, the margin of safety can be thought of as the extra cushion that should never be needed if everything works as anticipated. This extra cushion can take many forms including aircraft components built to greater strengths than are anticipated to be needed and separation standards that are far greater than normally necessary to keep aircraft from colliding. With the threshold concept, increases in the margin of safety beyond some point do not reduce the chances of a passenger being killed in an accident.

An alternative concept of a margin of safety is to think of safety in a continuum where any increase in the margin of safety reduces the probability of an accident. The fundamental difference with the two approaches is that with the threshold concept some reduction in the margin of safety may be possible without increasing the risk of accident whereas with the continuum concept any reduction in the margin of safety increases the risk of accident. Redundant systems can be thought of as an outgrowth of the continuum concept. Each system has some probability of failure, otherwise there would be no need for a backup. The greater the number of backup systems, the smaller the probability of total failure. A reduction in the number of backup systems increases the risk of accident, although the increase in risk may be extremely small.

While both the threshold and the continuum approach to the margin of safety are useful conceptually, neither lends itself to precise definition or measurement of the margin of safety. The margin of safety has many dimensions, some of which are best thought of as a continuum while others are best thought of as a threshold. Any single measure of the margin of such safety would have to combine measures of several dimensions and both concepts.

INCIDENT DATA

Accidents provide indisputable after-the-fact evidence that some element of safety for that particular flight was inadequate. Taken as a group, airline accidents can also provide considerable insight into persistent safety problems in various segments of the industry (Aviation Safety Commission). However, examining accidents may not be the best way to detect emerging safety problems. Instead, many have speculated that changes in the frequency of safety-related problems (incidents) may provide more sensitive measures of changing probabilities of aviation accidents. The usefulness of incident data hinges first on a correlation existing between incidents and accidents and, second, on the premise that careful tracking of changes in incidents may point to problems before they become apparent in accident data.

Much of the concern about aviation safety, particularly in the media, has been with midair collisions. Three types of incidents are often believed to be associated with the risk of midair collisions: air traffic control operational errors, pilot deviations, and near midair collisions. Before examining the correlation of these incidents with actual midair collisions, each of the types of incidents is examined.

Operational Errors

One duty of the nation's air traffic control system is to keep aircraft under its control separated from other aircraft and from obstructions. An operational error is defined as "... an occurrence attributable to an element of the air traffic control system which results in less than the applicable separation minima between two or more aircraft, or between an aircraft and terrain or obstacles and obstructions...obstacles include: vehicles/equipment/personnel on runways." (Federal Aviation Administration, 1988). These errors may occur in different parts of the air traffic control system. Air route traffic control centers (ARTCC) direct aircraft during the en route phase of flight over large areas and at many altitudes. Terminal facilities provide aircraft separation services during the phases of flight associated with takeoff and landing as well as ground control services. These facilities include airport traffic control towers, non-radar approach controls, and terminal radar approach controls (TRACON) (Federal Aviation Administration, 1987a).

Total reported operational errors have risen from 491 in 1976 to 1,222 in 1987 (Table 2). Between 1983 and 1984 errors more than doubled before decreasing slightly in 1985 and 1986 and remaining relatively steady between 1986 and 1987. The large increase in errors in 1984 can be attributed, to a large extent, to the operational error detection program (OEDP). The OEDP, called "snitch patch" by controllers, is a computer program that automatically records violations of en route separation standards at ARTCCs, removing any discretion in filing operational error reports. Operational error reporting has not been computerized at terminal facilities and is still based on reports filed by controllers.

The sharp increase in reported operational errors highlights a problem with much of the incident data. If some discretion is involved in filing reports, sensitivity and awareness of a problem or issue may alter the propensity to report. Thus, distinguishing between an increase in the underlying problem and an increase in the propensity to report or, in this case, the method of reporting, can be difficult.

Table 3 indicates that the en route share of total operational errors increased dramatically in 1983 and 1984, apparently in large part due to both the increased attention being paid to these errors and the removal of the discretion involved in reporting. When the snitch patch was introduced, controllers had difficulty making distinctions between aircraft separated by slightly more than the required five

TABLE 2

Operational Errors vs. Total Operations
1976-1987

Year	Total Errors	Total Air Traffic Operations[1] (000)	Overall error rate (per 100,000 air traffic operations)
1976	491	117,542	0.42
1977	507	124,216	0.41
1978	571	128,686	0.44
1979	612	135,174	0.45
1980	586	134,433	0.44
1981	457	128,323	0.36
1982	353	110,153	0.32
1983	723	116,722	0.62
1984	1,888	125,901	1.50
1985	1,402	129,848	1.08
1986	1,203	135,536	0.89
1987	1,222	141,411[2]	0.86

Source: U.S. Department of Transportation, Federal Aviation Administration, Office of Aviation Safety, Safety Analysis Division, *Profile of Operational Errors in the National Airspace System*, November 1987; Office of Aviation Safety, *National Aviation System Airspace Incidents, 1987 Summary Fact Sheet*, January 20, 1988; and data derived from computer files provided by the Office of Aviation Safety.

[1]Includes total instrument operations (ARTCC and Approach Control) and total airport tower operations.

[2]Estimated based on first nine months data.

miles and those separated by slightly less than five miles. Faced with a sharp increase in operational errors reported by the snitch patch, controllers responded by increasing separation well beyond the five-mile range. Beginning in 1986, software used by enroute controllers was refined so that a five-mile separation "halo" around each aircraft could be displayed on the screens. Aided by this new computer software, the number of en route errors declined in 1986 and was relatively constant in 1987. Anecdotal evidence also suggests controllers were able to reduce separation relative to 1984-1985 levels.

En route errors are categorized by their level of severity (major, moderate, minor, and other) based on a system that assigns points for the seriousness of the violation of horizontal and vertical separation standards (Federal Aviation Administration, 1987a). To be classified as a major en route operational error, the sum of the horizontal and vertical classification must equal twenty points—the maximum number of points. Thus, for a major error, there was both horizontal separation of less than one-half mile (worth ten points) and less than 500 feet vertical separation (worth ten points).

Table 3 suggests that very few ARTCC operational errors (1.1 percent or less) were classified as major errors between 1985 and 1987. Even major and moderate errors combined constituted less than twenty percent of en route operational errors. These data, coupled with conversations with controllers, suggest the initial increase in reports following the snitch patch were primarily for minor errors, although the lack of pre-1985 data makes it impossible to tell for sure. In addition to changes in reporting however, increased operations may well have had an impact on operational errors. As the airways and airspace around major airports becomes more congested, greater pressure is placed on controllers and more errors may result.

Examining these data also underscores a difficulty with defining an incident. Minor operational errors may pose little or no risk, they are counted because they are a violation of established FAA procedures and rules. Those rules, however, are inevitably somewhat arbitrary. Why is the minimum legal horizontal separation five miles instead of 4.5 or 5.5?

Pilot Deviations

A pilot deviation is defined as "...[t]he actions of a pilot that result in the violation of a Federal Aviation Regulation or a North American Aerospace Defense Command (NORAD) Air Defense Identification Zone (ADIZ) tolerance." (Federal Aviation Administration, 1988) Pilot deviation reports are filed by air traffic control, but data are only available since 1985.

As can be seen in Table 4, pilot deviations increased dramatically between 1985 and 1987. The table also indicates that general aviation (GA) operators are responsible for the largest number of pilot deviations, accounting for more than 53 percent of total deviations during the period. However, FAA acknowledges several limitations associated with the database. "Automatic reporting of altitude errors in the en route environment through the Air Traffic Control (ATC) system, stepped up enforcement policies against Terminal Control Area (TCA) violators, and an overall awareness on the part of

TABLE 3

Operational Errors by Year (percentage of total in parentheses)

Total Errors by Category

Year	Terminal	Enroute (ARTCC)	Flight Service Station (FSS)	Total
1980	356 (60.8%)	230 (39.2%)	——	586
1981	289 (63.2%)	168 (14.8%)	——	457
1982	188 (53.3%)	164 (46.5%)	1 (0.2%)	353
1983	292 (40.4%)	429 (59.3%)	2 (0.3%)	723
1984	388 (20.6%)	1497 (79.3%)	3 (0.1%)	1888
1985	409 (29.1%)	992 (70.7%)	3 (0.2%)	1404
1986	395 (32.8%)	808 (67.2%)	0	1203
1987	401 (32.8%)	820 (67.1%)	1 (0.1%)	1222

ARTCC Errors by Level of Severity

Year	Total ARTCC Errors	Major	Moderate	Minor	Other
1985[1]	992	3 (0.3%)	139 (14.0%)	847 (85.4%)	3 (0.3%)
1986[1]	808	9 (1.1%)	136 (16.8%)	646 (80.0%)	17 (2.1%)
1987	820	7 (0.9%)	151 (18.4%)	645 (78.7%)	17 (2.1%)

Source: U.S. Department of Transportation, Federal Aviation Administration, Office of Air Traffic Evaluations and Analysis, *Air Traffic Operational Error Analysis, Fiscal Year 1986 (1987)*; Office of Aviation Safety, *National Aviation System Airspace Incidents*, *1987 Summary Fact Sheet*, January 20, 1988; and data derived from computer files provided by the Office of Aviation Safety.

[1]To highlight one of the data problems, the data reported in the *Air Traffic Operational Error Analysis* do not exactly match the data reported in the *National Aviation System Airspace Incidents* summary.

controllers concerning pilot deviation incidents has greatly affected the volume of reports received..." (Federal Aviation Administration, 1987c) In addition, there is some ambiguity about applying the definition of pilot deviations and ATC has some discretion in whether or not not to report a specific incident. (Federal Aviation Administration, 1987c) Part of the increase may represent increased risk from more pilot deviations, but part may be due to more stringent reporting practices by ATC as a result of the automated reporting systems and increased awareness of pilot deviations in the aftermath of the midair collision over Cerritos, California in August 1986.

One of the major concerns associated with pilot deviations is the possibility that an accident will occur, especially a collision with another aircraft. Incidents involving loss of separation with another aircraft decreased in 1987 after increasing sharply in 1986 and the number of near midair collision reports that have been filed as a result of the pilot deviation has remained roughly constant.

Near Midair Collisions (NMACs)

A near midair collision is defined as "...an incident associated with the operation of an aircraft in which a possibility of collision occurs as a result of

TABLE 4

Pilot Deviation Reports

Year	Total Pilot Deviations	Loss of Standard Separation	General Aviation	Airspace Violated	NMAC Report Filed
1985	1783	770	1010	453	32
1986	2544	1108	1354	1425	38
1987	3521	583	2159	2086	32

Source: U.S. Department of Transportation, Federal Aviation Administration, Office of Aviation Safety, Safety Analysis Division, *Selected Statistics Concerning Reported Pilot Deviations (1985-1986)*, October 1987; data derived from computer data files provided by the Office of Aviation Safety.

proximity of less than 500 feet to another aircraft, or an official report is received from an air crew member stating that a collision hazard existed between two or more aircraft." (Federal Aviation Administration, 1988). The first part of the definition—two aircraft with less than 500 feet separation between them—provides a standard about when a near midair collision incident has occurred, but judging distance under near midair collision circumstances clearly involves some subjectivity. The second part of the definition—the existence of a collision hazard—adds even more subjectivity. Near midair collision reports are filed by pilots. The perception of risk in a near midair collision and the propensity to report may vary among pilots and also vary over time. For example, if more attention is paid to the issue in the media, pilots may be more inclined to report such incidents. There are two major sources of near midair collision data—the FAA's Office of Aviation Safety database and NASA's Aviation Safety Reporting System. A change report processing procedures in 1985 may affect the comparability of FAA's pre- and post-1985 near midair collision data.

FAA Near Midair Collision Database. Total reports to the FAA of near midair collisions increased by 24 percent between 1983 and 1984, by 28.7 percent between 1984 and 1985, by 10.8 percent between 1985 and 1986, and by 26.5 percent between 1986 and 1987 (Table 5). The FAA classifies near midair collision reports by degree of hazard. A critical hazard is ". . . a situation where collision avoidance was due to chance rather than an act on the part of the pilot. Less than 100 feet of aircraft separation would be considered critical." A potential hazard is "...an incident which would probably have resulted in a collision if no action had been taken by either pilot. Closest proximity of less than 500 feet would usually be required in this case." No hazard is "...when direction and altitude would have made a midair collision improbable regardless of evasive action taken" (Federal Aviation Administration, 1987b). The unclassified category refers to NMAC reports where the inspector was unable to determine the hazard category. During the 1983-1987 period critical and potential hazards accounted for between 65 and 80 percent of total near midair collision reports, suggesting that a large proportion of the reports filed involved a clear risk to safety.

NASA's Aviation Safety Reporting System Data. The Aviation Safety Reporting System (ASRS) originally was set up by the FAA to accumulate information on near midair collision incidents. It was designed as a voluntary reporting system, but after concerns were raised about possible repercussions from reports, the system was transferred to the National Aeronautics and Space Administration (NASA). Presently, the data system is managed by a third party contractor with no regulatory authority. Because all ASRS reports are voluntarily submitted, there is no way to determine if the data is a representative sample of all such incidents (Aviation Safety Reporting System Office). Also, not all members of the nation's aviation system are equally aware or equally willing to make reports to ASRS, introducing possible reporting biases into the data set. The two data bases have relatively little overlap with less than 10 percent of FAA near midair collision reports found in the ASRS data base (Office of Technology Assessment). Even for near midair collisions involving air carriers, only 18 percent in the FAA data base were found in the ASRS data.

Reports of near midair collisions to ASRS have remained relatively stable over the 1981-1987 period (Table 6). Most of the NMACs were reported in terminal airspace not supervised by air traffic control radar. The overall trend is in sharp contrast to the FAA data which showed a steady upward trend. The FAA data suggest NMACs are becoming a greater problem, in absolute terms, while the NASA data suggest the absolute number of NMACs has declined since 1984.

CORRELATION WITH ACCIDENTS

The first question in assessing the use of incident data in monitoring changes in aviation safety is the correlation between the risk that appears to be indicated by the incidents and the appropriate type of accident. Air traffic control operational

TABLE 5

Pilot Reported Near Midair Collisions by Class of Hazard FAA Data (percentage of total in parentheses)

Year	Total	Critical	Potential	No Hazard	Unclassified
1983	475	97(20.4%)	284(59.8%)	85(17.9%)	9(1.9%)
1984	589	127(21.6%)	317(53.8%)	115(19.5%)	30(5.1%)
1985	758	180(23.7%)	423(55.8%)	133(17.5%)	22(2.9%)
1986	840	162(19.3%)	471(56.1%)	196(23.3%)	11(1.3%)
1987	1063	171(16.1%)	528(49.7%)	237(22.3%)	127(11.9%)

Source: U.S. Department of Transportation, Federal Aviation Administration, Office of Aviation Safety, Safety Analysis Division, *Selected Statistics Concerning Pilot Reported Near Midair Collisions (1983-1986)*, October 1987 and data derived from computer files provided by the Office of Aviation Safety.

TABLE 6

Near Midair Collision Reports by Air Traffic Control Category Aviation Safety Reporting System Data (percentage of total in parentheses)

Year	Total NMAC Reports	Percentage of Total Conflict Reports	Incidents in Terminal Control Airspace	Incidents in Other Terminal Airspace	Incidents Occurring Enroute
1981	434	31.7%	68(15.7%)	278(64.1%)	88(20.3%)
1982	382	39.7	44(11.5%)	258(67.5%)	80(20.9%)
1983	450	38.6	60(13.3%)	301(66.9%)	89(19.8%)
1984	530	29.2	60(11.3%)	317(59.8%)	153(28.9%)
1985	526	39.0	68(12.9%)	201(38.2%)	257(48.9%)
1986	395	31.1	69(17.5%)	215(54.4%)	111(28.1%)
1987	371	28.2	61(16.4%)	215(58.0%)	95(25.6%)

Source: Data provided by Battelle Aviation Safety Reporting System Office.

errors, pilot deviations, and near midair collisions all appear to be indications of risk of actual midair collision. Table 7 lists actual midair collisions from 1968 through 1987. As the table indicates, the number of midair collisions changed little, especially in the post-deregulation era.

Operational errors do not seem closely correlated with midair collisions. Terminal airspace operational errors have essentially no correlation with a correlation coefficient of negative 0.03 based on the eight years of available data. ARTCC operational errors have been influenced by the introduction of the snitch patch and the controllers' adjustment to it. In the four years of the post-snitch patch era, the correlation with midair collisions is only 0.20. Over the same period, operational errors are actually negatively correlated with the FAA's count of total near midair collisions

TABLE 7

Midair Collisions by Year 1968-1987

Year	Total	Fatal	Fatalities
1968	37	23	69
1969	28	12	122
1970	37	21	55
1971	32	20	95(1)1
1972	25	13	41
1973	24	12	29
1974	34	19	48
1975	29	13	47
1976	31	24	64
1977	34	17	41
1978	35	23	185(7)1
1979	26	14	34
1980	24	19	55
1981	30	13	47
1982	29	18	59
1983	12	7	2 2
1984	25	14	47
1985	25	14	36
1986	27	16	112(15)1
1987[2]	21	9	21

Source: U.S. Department of Transportation, Federal Aviation Administration, Office of Aviation Safety, *National Aviation System Airspace Incidents*, *1987 Summary Fact Sheet*, January 20, 1988.
[1]On ground fatalities
[2]Preliminary data

(-0.84) and critical near midair collisions (-0.83).

Because there are only three years of pilot deviation data, it is not possible to draw reliable conclusions about their correlation with midair collisions. Pilot deviations resulting in a loss of separation are highly correlated (0.94) over the three years, but total pilot deviations, deviations that resulted in violation of restricted airspace, and deviations by general aviation pilots are negatively correlated. Three years of data are simply too little upon which to base a conclusion.

Near midair collisions are also not strongly correlated with midair collisions. Indeed, near midair collisions as reported to the Aviation Safety Reporting System show no correlation (-0.08) over the seven years of available data. Midair collisions reported to the FAA have a correlation coefficient of only 0.44, although critical NMACs are somewhat higher at 0.71. The FAA correlation is based on only five years of data.

The lack of correlation between potential midair collision incidents and accidents is disappointing to those seeking insight into aviation safety, but may not be surprising in light of the characteristics of the incident data. First, of course, the data has not been collected long enough to find a relationship even if one existed. Second, because of discretion in reporting incidents, changes in the data reflect both changes in the number of incidents and changes in the propensity to report. It is only a change in the number of incidents that one would expect to be related to accidents, not a change in reporting.

Finally, even if the data problems were to be solved, one would not expect a constant relationship between incidents and accidents. To oversimplify, improving aviation safety consists of two tasks: reducing the number of hazardous incidents and reducing the chance that a hazardous incident will end in an accident. A considerable amount of effort in the aviation industry is devoted to this second task—changing the relationship between incidents and accidents. In the case of midair collisions, the development and eventual implementation of collision avoidance systems is specifically intended to make sure that operational errors, pilot deviations, and near midair collisions do not become midair collisions. Windshear provides another example of pursuing both tasks. There are efforts both to detect windshear conditions so that pilots can avoid them and to improve pilot training and equipment so that if windshear is encountered, there is a better chance of avoiding an accident.

CONCLUSIONS

Data describing air traffic control operational errors, pilot deviations, and near midair collisions have the potential to provide insight into the frequency with which hazardous incidents which could lead to midair collisions occur. To be useful, however, the definitions of these incidents must remain the same over time; the severity of the risk posed by specific incidents must be taken into account; and the discretion in reporting incidents must be reduced to the point where the propensity to report incidents does not change over time.

No systematic pattern of correlation was found between operational errors, pilot deviations, or near midair collisions and actual midair collisions. In part, the lack of correlation may be because too little data are available and, in part, because changes in incident data are the combined result of both changes in the number of incidents and changes in the propensity to report. With improvements in incident data reporting, these data have the potential to provide insight into changes in exposure to risk in aviation. However, even when consistently reported data on these incidents are available in sufficient quantity, the relationships between incidents and accidents are likely to change as safety technology and practice are improved. Even so, incident data can eventually provide important indications of changes in exposure to some elements of risk.

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ENDNOTES

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