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FATIGUE, PILOT DEVIATIONS AND TIME OF DAY

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SUMMARY

This study examined the relationships between pilot fatigue, pilot deviations, reported incidents, and time of day. Part I of the study used data from NASA's Aviation Safety Reporting System (ASRS), which is based on voluntary reports by flight crews, air traffic controllers, etc. Part II was based on the FAA Pilot Deviation data and incident data.

In Part I we analyzed a sample of 200 reports from 1985 and 200 reports from 1987, plus 100 reports from late 1987 and early 1988 that had been selected because of possible association with fatigue. (These sample sizes were reduced somewhat by eliminating reports about planes with gross takeoff weights of less than 5,000 pounds, to eliminate general aviation cases.) Cases in all three samples were classified with regard to type of deviation (e.g., altitude deviation, runway incursion) and reported contributing factors (e.g., fatigue, distraction). In addition, a special tabulation of 9,398 ASRS cases from 1988 was analyzed to identify the characteristics of cases chosen by ASRS investigators for detailed computer entry with narrative sections. (All ASRS cases were entered in detail in 1985, but not in 1987 and 1988.)

The main findings in Part I were:

*Cases selected for detailed entry in the ASRS file were especially likely to involve conflicts and air traffic control problems, and less likely to involve altitude and heading deviations than cases not so selected.

*Distraction was disproportionately involved as a factor in altitude deviations. In 1985 (the most representative sample, in which almost half of all cases were altitude deviations), distraction was the primary factor in 31% of the altitude deviations, compared to 11% of other cases.

*Cases in the late night and evening hours disproportionately involved fatigue as one of the contributing factors (67% and 39%, respectively, compared to 20% in the daytime).

*Runway transgressions occurred disproportionately in the evening (43% of all runway transgressions occurred between 1800 and 2359 hrs).

*Fatigue was especially likely to be a factor in smaller aircraft (small, light, and medium transport aircraft): 40% of cases in the fatigue set were smaller aircraft, compared to 14% of cases in the 1985 Sample. Fatigue was also associated with smaller aircraft in the 1985 Sample.

Part II analyzed information on FAA-reported pilot deviations and incidents in relation to denominator data that summarized the hourly operations (landings and takeoffs of scheduled flights) at major U.S. airports. Using as numerators FAA data on pilot deviations and incidents reported to the FAA, we calculated rates by time of day. Pilot age was also analyzed in relation to time of day, phase of flight, and type of incident.

Some of the findings in Part II have not been confirmed by 1988 data and must be considered tentative; this does not refer to the data on numbers of operations, which are based on very large sample sizes. Findings of interest:

*The number of commercial operations was highest at about 1800 hours, with lower peaks at 0800 and 1300.

*The rate of pilot deviations declined during the day from 24 per million operations at 0600-0759 to 15 per million operations at 1800-midnight, with a pronounced peak at 1400-1559.

*The rate of pilot deviations from midnight to 0559 was essentially the same as the overall rate, which was 19.7 deviations per million operations.

*The rate for altitude deviations had a pronounced peak from 1400-1559.

*The rate of runway transgressions per million operations tended to be high in the morning, lower during the day, and to rise again in the evening.

*The rate of pilot-induced incidents per million operations was highest from 0600-0959, with a lower peak from 1200-1449; as with pilot deviations, the rate from midnight to 0600 was the same as for the overall rate.

*No consistent relationships were found between pilot age and other variables.

BACKGROUND

NASA researchers have compared the performance of air transport crews after a three-day, high-intensity duty cycle with crews that had just had at least three days off-duty (1). In simulated flight scenarios, crews performed even better in the post-duty (more fatigued) state than in the pre-duty state, apparently because of the better communications and coordination among crew members who have worked together for several days.

Despite the great importance of crew coordination, fatigue *per se* remains an important subject, as it is known to be associated with deterioration in performance under experimental conditions. Analysis of data from the NASA Aviation Safety Reporting System (ASRS) from 1976-1980 revealed that 21% of air transport crew errors were either directly or indirectly attributed to fatigue (2). In another study of U.S. Naval aircraft mishaps, fighter and helicopter pilots who had worked at least 10 hours in the previous 24 hours were significantly more likely to have been among pilots causally linked to the mishap (3).

Of importance to many aircrew members are the effects of sleep disruption which result from attempts to accommodate to an unusual work schedule. These effects are cumulative and the risk of performance error due to a sudden, overpowering sleepiness increases with continued sleep loss or "sleep debt" (4). Although many experts do not equate sleepiness with fatigue, sleepiness is viewed by many aviators as the most operationally significant aspect of air crew fatigue (5). The timing of trips and not necessarily the length of duty day or number of segments flown appeared to contribute more to the development of fatigue among the short haul pilots studied (6).

With computers now available to develop new schedules that maximize the work load within legal limits, it is urgent to pursue research on the effects of long duty hours and fatigue. In particular, research is needed on real world incidents such as altitude deviations and runway incursions as they relate to fatigue and crew schedules.

NASA's Aviation Safety Reporting System (ASRS) allows pilots to anonymously report incidents such as altitude or course deviations, failure to follow instructions of controllers, and errors or confusion when approaching destination airports. Some ASRS reports cite fatigue, lack of sleep, or long periods on duty as factors contributing to the incident. The relationship between fatigue of flight crews and airplane crashes or other incidents has not been directly measured. However, data from other modes of travel show the adverse effects of long duty hours. For example, the risk of crashes among tractor trailer drivers who have been on duty for more than 8 hours has been shown to be almost double the risk of truck drivers as a whole (7). Analysis of the temporal distribution of 6,000 single vehicle traffic crashes attributed to "falling asleep at the wheel" revealed a major peak between 1:00 a.m. and 4:00 a.m.; a small secondary peak was evident between 1:00 p.m. and 4:00 p.m. (4). (Circadian rhythm effects are greatest during the hours of approximately 2:00 to 7:00 a.m. and to a lesser extent during a midafternoon period from approximately 2:00 to 5:00 p.m.).

Although hour of the day is not a surrogate for pilot fatigue, there are at least four reasons for a relationship between the two variables: 1) the later it is in the day, the more hours are likely to have elapsed since a pilot slept; 2) there is some correlation between number of hours on duty and time of day: i.e., early in the morning, most pilots will have just come on duty, and pilots flying late in the evening will generally have flown for a number of hours; 3) a "low spot" often occurs at 3-5 p.m. when people are apt to feel drowsy or less alert; 4) at certain hours of the day when air traffic is heaviest, a pilot's workload may be heavier, resulting in more fatigue.

In 1986, the total number of pilot deviations (PDs) was highest at 3-4 p.m. (1). Hourly counts were not separately examined for air carriers, however; this step is important since air carriers account for less than 15% of the reported PDs and therefore are "masked" by the far larger number of general aviation PDs. Nor had rates of pilot deviations or incidents per million operations been calculated in relation to local time; such an analysis was needed in order to know whether hourly differences in the number of events are simply due to differences in the number of flights.

The present study provides the first data on rates of pilot deviations by hour of the day, using an innovative procedure for developing denominator data. The study was designed to answer the following questions:

- What are the characteristics of reported pilot deviations?
- How do the ASRS cases selected for detailed computer entry differ from the 1985 cases, all of which were entered?
- How do the "fatigue" cases differ from other cases with regard to type of incident and other variables?
- How do position deviations differ from other cases with regard to potentially contributing factors?
- Do airline pilot deviations reported to the FAA occur disproportionately at any hour of the day?
- Is there any relationship between pilot age and phase of operation, time of incident, or type of incident?

PART I: ASRS DATA

METHODS AND MATERIALS

The following sets of data were used in our analyses of ASRS cases:

1. 1985 SAMPLE. A sample of 200 cases from 1985 was drawn as every nth case, to provide representative cases throughout the year. After eliminating reports on aircraft weighing less than 5,000 pounds (likely to be general aviation cases) and reports warning of a hazard that did not affect the crew reporting the hazard, there were 177 cases.

2. 1987 SAMPLE. Similar to the 1985 Sample except that it excluded all abbreviated records without narratives. (In 1985, virtually all cases contained narratives.) After exclusions similar to the ones for the 1985 Sample, there were 148 cases.

3. FATIGUE SET. This group of cases contained 100 reports sent to Dr. R. Curtis Graeber involving flight crew fatigue, from April 1987 through March 1988. After exclusions similar to those above, there were 93 cases.

4. 1988 TABLES. The first 9,398 cases filed in 1988 (January through June, with some cases from July and August) were summarized in tables that differentiated between cases with narratives ('Short Forms') and those without ('Abbreviated Forms').

5. OPERATIONS SAMPLE. A sample of 56,298 operations during January and July, 1986 was drawn based on the 35 U.S. airports with the largest numbers of operations (landings and takeoffs). The local time of these operations was used as a national denominator, to give the hourly distribution of operations in the U.S. The methodology for this sample is described more fully in the section on pilot deviations.

Each case in the 1985 and 1987 Samples and the Fatigue Set was reviewed and the data were coded. Most coding was straightforward, since the ASRS categories of anomalies, aircraft type, etc. were used without revision.

The only variable that required the use of judgment and understanding of the pilot's task in order to code it was our variable called 'Factor.' This referred to the contributing factor that appeared to be most important. The major groups of contributing factors were communication problems, distraction, fatigue, errors, and malfunctioning equipment. Up to four factors could be coded for each case. (For example, in one case a heading deviation occurred because a first officer who was unfamiliar with the task had loaded the wrong route description into the computer; this was coded as both an error and as fatigue, since he mentioned fatigue and a poor night's sleep the previous night.) Contributing factors were coded by an experienced pilot who reviewed each case. Factors are described on Table 1.

RESULTS

SELECTION FACTORS FOR ASRS CASES CHOSEN FOR DETAILED COMPUTER ENTRY

Two sets of data suggest the factors that influence the cases chosen for detailed computer entry, complete with narratives. The first of these data sets were the 1988 Tables. The major differences (Table 2) were:

*Altitude and heading deviations and non-adherence to requirements or clearances made up 60% of cases without narratives, but only 22% of cases selected for narrative reports.

*Conflicts, including near midair collisions, made up 18% of cases with narratives but only 2% of those without.

*Air traffic control problems made up 24% of the primary problems in cases selected for narratives, compared to 3% of cases not selected.

The second set of comparison data that reflected the influence of case selection on the cases chosen for detailed entry was the comparison of 1985 vs 1987 cases -- since all cases were described in narratives in 1985, but only selected cases were described in 1987. In light of the data in Table 2 on the 1988 cases, the differences between the 1985 and 1987 samples (Table 3) are not surprising:

*Altitude deviations made up 4% of the cases in the 1985 Sample, but only 17% in the 1987 Sample.

*Equipment problems were more common among the 1987 Sample than in the 1985 Sample.

*Runway transgressions were more common in the 1987 Sample. (In 1988, on the other hand, runway cases appeared in similar proportions in cases with and without narratives. Therefore it is surprising that they appeared to be over represented in the 1987 narrative cases; the difference may result from small numbers.)

FACTORS CONTRIBUTING TO ANOMALIES

Table 4 shows the distribution of the primary factor listed in each sample. As would be expected, fatigue was the primary factor in 81% of the cases in the Fatigue Set. Only 2% of cases in the 1987 sample were categorized with fatigue as the primary factor, compared to 6% in 1985, suggesting that the selection factors that influenced which of the 1987 cases were chosen for detailed ("Short Form") reports operated to reduce the chance of selecting a case in which crew fatigue was a factor.

Communication and distraction were especially prominent factors in the 1985 Sample, compared to the other two samples. Altitude deviations made up half of this sample, and were disproportionately attributed to distractions (Table 5): distraction was the primary factor in 31% of (26/83) of all altitude deviations compared to 11% (10/94) of other cases ($X^2 = 11.6$, $p < 0.01$). It should be emphasized that this finding is for the 1985 sample, which is the most representative of the three samples.

All cases in which fatigue was coded as the primary factor were further subdivided as to the apparent cause of the fatigue (Table 6). Although the numbers are small, they indicate that flight time/duty time and end-of-day tiredness were the major factors.

Table 7 shows the percentage of cases in which fatigue was coded as <u>any</u> of the contributing factors, in relation to the anomaly.

TIME OF DAY

Late night hours were over-represented in the fatigue set. The national sample of operations showed that 2% of all operations occur at night between 0000 and 0559 hours. In contrast, 13% of the cases in the Fatigue Set (12 out of 93) occurred during this period ($p < 0.01$). Fatigue cases were also slightly more likely to occur in the evening (1800-2359 hours) than were cases in general (Table 8).

Disproportionately, the anomalies in the 12 late night fatigue cases were deviations. Seven of the 12 cases (58%) that occurred at night were either altitude, track, or heading deviations. In contrast, only 37% of all cases in the fatigue set (34 out of 93) were deviations ($X^2 = 2.8$, $p = 0.1$ reflecting only borderline significance).

When all cases from the three sets were combined, those cases in which fatigue was noted as a contributing factor (not necessarily the primary factor), cases in the late night and evening hours were especially likely to involve fatigue (67% and 39%, respectively, compared to 20% in the daytime) (Table 9).

Runway transgressions seemed to occur disproportionately in the evening, in both the fatigue set and the 1987 sample. In the fatigue set, 40% of the runway transgressions (4/10) occurred between 1800 and 2359 hours, and in the 1987 sample, 60% (6/10). For the three samples combined, 43% of all runway transgressions occurred in the evening, compared to 23% for all anomalies combined. ($X^2 = 5.4$, $p < 0.025$)

TYPE OF AIRCRAFT

Fatigue was most likely to be a factor in smaller aircraft (i.e., small, light, and medium transport aircraft, with gross takeoff weights of 5,000 - 60,000 lbs) (Table 10). Forty percent of all aircraft in the Fatigue Set (37/93) were smaller aircraft, compared with 14% of aircraft in the 1985 Sample (believed to be the most representative of the three samples). The relationship was also apparent within the 1985 sample, in which 45% (5/11) of the cases in which fatigue was listed as the first factor were smaller aircraft, compared with 14% of all the cases in this sample ($X^2 = 10.2$, $p < 0.01$). The 1987 Sample had too few (only 3) fatigue-related cases for a corresponding analysis.

Although some of the numbers involved are small, the finding is consistent with the workload and taxing schedules of pilots of commuter aircraft, and suggest the need for further investigation.

PART II: PILOT DEVIATIONS AND INCIDENTS

METHODS AND MATERIALS

Pilot Deviations: Computerized data on pilot deviations were provided by the FAA for the years 1985-87. Data for 1985 were incomplete because the data system was not fully implemented until the latter half of 1985; therefore, analyses were based on 1986-87 data. Variables used in the analyses included hour of the day, type of deviation, phase of flight, and pilot age. Air carriers and commuters were combined for purposes of calculating rates, since the number of operations (the denominator) were determined for all scheduled carriers.

Incidents: Tabulations of pilot-induced incidents for 1984-86 were provided by the FAA. These were examined for relationships by time of day, flight phase, and pilot age.

Operations: Denominator data for calculating rates were derived from raw data provided by the FAA: the numbers of arrivals and departures during each hour of the day for 38 major airports. From the list we selected the 35 busiest airports in the contiguous United States. For these 35 airports, the number of commercial departures on an average day in January, 1986, ranged from 163 at Fort Lauderdale to about 1100 at Atlanta and O'Hare.

Samples were drawn from each of two one-week periods that began January 16 and July 15, 1986. The sample included, for each of the 35 airports, all arrivals during one day during each period and all departures during another day from each period. Thus, for each airport, data were used from four different days. The seven days of the week were equally represented. Time was converted from GMT to local time and the numbers were entered into a computer for summation and analyses.

The sample contained 56,298 scheduled operations (arrivals and departures). There were 33,934,000 scheduled operations nationwide in 1986-87 by U.S. airlines and commuters; therefore each operation in the sample was multiplied by 602.8 (33,934,000 divided by 56,298) to provide an estimate of the number of operations in the United States at each hour of the day.

RESULTS

Operations. The number of operations was 6% larger in July than in January, but the two distributions did not differ markedly; both showed a peak at 1800 hours, with slightly lower peaks at 0800 and 1300 (Figure 1). Departures differed from arrivals primarily in the larger numbers during the two-hour period beginning at 0800 and also at 1400; both showed a peak at about 1800 hours (Figure 2).

<u>Pilot deviations:</u> (Note: many of the following findings have not been confirmed by 1988 data; until further analyses are done, they should be regarded as tentative and possibly the result of chance variations associated with small numbers.)

There were 820 pilot deviations in 1986-87, and the time of day was recorded for 757 (91%). The temporal distribution for pilot deviations differed markedly from the distribution of operations. In comparison with the number of operations, there were more pilot deviations than would have been expected from about 0600 to 1600 hours, and fewer than expected from about 1800 to midnight (Table 11).

These differences are reflected in the overall <u>rates</u> of pilot deviations, which declined through the day from about 24 per million operations at 0600-0759 to 15 per million at 1800-midnight, with a pronounced peak at 1400-1559 (Figure 3).

The rate for altitude deviations showed a pronounced peak for 1400-1559 hours (Figure 4). The rate of runway transgressions, on the other hand, was high in the early morning and declined during the day, rising somewhat in the evening.

For all hours and all types of pilot deviations combined, the rate was 19.7 deviations per million operations. During the late night hours, between midnight and 0559, the rate was 18.8, essentially the same as for all other hours combined. The rate for these hours is not shown on the Figures because it was calculated for a 6-hour period (rather than two-hour intervals) due to the small numbers (only 15 deviations occurred in the 6-hour period.

No relationship was found between pilot age and phase of flight. Correlations between pilot age and time of day appeared likely to be related to seniority -- i.e., older pilots were less likely to be involved in cases at night or before 0800, and more likely to be involved at the hours likely to be chosen by senior pilots, between 0800 and 1600.

<u>Incidents:</u> Data were provided for 731 'pilot-induced' incidents during 1984-1986. About half were due to either altitude deviations (30%) or failure to follow approved procedures or instructions (17%). This file has since been changed to eliminate the pilot deviations, so the two files no longer overlap. Until 1985, this was the only source of information on pilot deviations. While we consider the more recent, and larger, body of data on pilot deviations to be more relevant, the review of the incident data tabulations is included because it was specified in our proposal.

The rate per million operations was highest from 0600-0959, then decreased, then had an intermediate 'peak' from 1200-1559 (Figure 5).

As in the case of pilot deviations, the number of incidents between midnight and 0559 was close to the average rate for all hours combined.

There appeared to be a correlation between pilot age and phase of flight, with pilots age 46-55 especially apt to be involved in climb-to-cruise cases and pilots age 56+ over-involved in descents. Since the pilot deviation cases showed no such relationship, it is likely that the finding in this data set was spurious.

COMMENT

Several general conclusions are suggested by these analyses of data from NASA's ASRS file and the FAA.

1. Although the numbers are small, the pilot deviation data from FAA suggest that there are marked variations in <u>rates</u> of deviations, in relation to time of day. These variations cannot be studied when data are presented in 6-hour periods. Hour of the day (at least the first two digits of local military time) should be made a part of ASRS records. If this cannot be accomplished in the present system without compromising anonymity, it would be possible to create two ASRS files -- one including hour of the day but not airport facility or state, and the other including such geographic data but not hour of the day. Because of the large numbers of cases in the ASRS file and the information available in the narratives, it would be an ideal -- and perhaps the only -- source of good data on some of the specific things happening at various times of day.

2. Because of the selection factors that influence the choice of ASRS records for detailed investigation ('short form'), with narratives, it is difficult to interpret data based on cases based on these investigations. Consideration should be given to routinely doing a detailed form for a sample of cases -- perhaps every hundredth case -- so that it will always be possible to know what the universe of cases looks like, rather than just the most interesting ones.

3. One finding that is not surprising nevertheless merits further attention: the relationship between fatigue and smaller aircraft suggests the need for attention to the demanding tasks and schedules of commuter pilots.

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Table 1
Factors
NASA ASRS REPORT CODING KEY
Revised 3/6/89

	# coded as 1st Factor Fatigue set	1985 sample	1987 sample
Distraction			
DU - Unknown	1	1	0
DI - Inoperative aircraft system	0	5	0
DC - Communication difficulty	0	3	2
DA - ATC anomaly	0	1	0
DT - Conflict	0	4	2
DX - Weather	0	3	3
DK - Workload	0	11	7
DZ - Interruption	0	3	2
DP - Cockpit confusion	0	3	0
DO - Other	1	2	1
Communication			
CU - Unknown	0	0	1
CI - Inattention, pilot or controller	0	3	1
CC - Technique, controller	0	7	2
CM - Misunderstood clearance or readback	3	22	9
CB - Between flightdeck crewmembers	3	1	1
CO - Other	0	7	4

Table 1 (cont.)

	# coded as 1st Factor Fatigue set	1985 sample	1987 sample
Fatigue			
FF - Flight time/duty time.	32	6	1
FS - Sleep lack	8	1	0
FW - Workload	7	0	1
FE - End of Day	14	3	1
FU - Unknown	12	1	0
FO - Other	2	0	0
Malfunction			
MU - Unknown	0	0	2
MI - Inoperative autopilot system	0	9	5
ML - MEL item	0	1	1
ME - Engine, or engine component failure	0	0	5
MR - Radios	0	0	1
MN - Navigation radios or component	0	1	1
MH - Altimeters	0	0	3
MO - Other	0	6	8
Error			
ER - Setting radios	3	5	1
EN - Navigation	0	6	5
EI - Inattention, crew	2	22	16
EM - Failure to monitor	1	7	5
EC - Controller	2	14	33
EH - Setting Altimeters	0	0	0
EO - Other	2	3	10

Table 1 (cont.)

	# coded as 1st Factor		
	Fatigue set	1985 sample	1987 sample
See, Failure To			
SV - Poor Visibility	0	2	1
SM - Failure to monitor	0	0	1
SU - Unknown	0	3	2
Other			
RS - Safety Report, General	0	4	2
RT - Training Report	0	1	0
UN - Unknown or no contributing factors	0	1	1
OT - Other	0	4	3
NA - Not Applicable	0	1	0
No Factor Coded	0	0	4
Total	93	177	148

Table 2
Summary of Major Differences Between Abbreviated and Short Forms
(Cases entered in ASRS data base 1/1/88 - 10/7/88)

	% of Abbreviated (no narrative)	**% of Short Forms** (with narrative)
Type of Anomaly		
Altitude/hdg deviation	35.2	12.2
Non-adherence reqmt/clnc	24.5	10.2
Conflict (all categories)	1.8	17.7
Acft equip problem	3.4	8.8
Less than legal sep	0.6	7.2
Type of All Traffic Incident		
Pilot deviation	75.6	35.8
Emergency	0.0	6.1
NMAC	0.0	9.4
Operational deviation of error	0.0	16.1
Type of Primary Problem		
Flight Crew	81.5	48.4
Aircraft	2.2	12.5
Airport	0.7	3.9
Air Traffic Control	3.0	24.2
Type of Reporter		
Flight crew	99.4	87.7
Controller	0.3	10.9
Time of Occurrence		
0001-0600	1.9	2.4

For detailed tables from which this summary was derived see Appendix A.

Table 3
Anomalies in ASRS Reports
Percent Distribution

	Fatigue Set (N=93)	1985 Sample (N=177)	1987 Sample (N=148)
Alt. Deviation	22	47	17
Track/Hdg Dev	15	10	10
Non Adherence	5	5	3
Conflict	12	17	24
Rwy Trans	11	2	7
Weather	1	2	4
Equipment	3	5	11
Other	31	13	24
Total	100%	101%	100%

Table 4
Primary Contributing Factor in ASRS Cases
Percent Distribution

	Fatigue Sample (N=93)	1985 Sample (N=177)	1987 Sample (N=148)
Communication	6	23	12
Distraction	2	20	12
Error	11	32	47
Fatigue	81	6	2
Malfunction	0	10	18
Other	0	9	9
	100%	100%	100%

Table 5
Anomaly by Primary Contributing Factor
1985 Sample of ASRS Data

	Com	Dis	Err	Fat	Mal	Oth	Total
Alt. Deviation	17	26	26	5	9	0	83
Track/Hdg Dev	5	3	8	1	1	0	18
Non Adherence	4	1	0	3	0	0	8
Conflict	4	4	13	1	0	8	30
Rwy Trans	0	0	3	0	0	0	3
Weather	2	0	1	0	0	1	4
Equipment	0	1	1	0	6	0	8
Other	8	1	5	1	1	7	23
Total	40	36	57	11	17	16	177

Key: Com = Communication, Dis = Distraction, Err = Error,
Fat = Fatigue, Mal = Malfunction, Oth = Other

Table 6
Cause of Fatigue in Cases where Fatigue was Primary Factor
ASRS Data

Cause of Fatigue	Fatigue Set (N=75)	1985 Sample (N=11)	1987 Sample (N=3)
Flight/duty time	43	55	33
Sleep lack	11	9	0
Workload	9	0	33
End of day	19	27	33
Unknown/other	19	9	0
Total	101%	100%	99%

NOTE: For each data set the table includes only the cases in which fatigue was coded as the primary factor. These percents are based on very small numbers; they are converted to percentages only for the purposes of comparison.

Table 7
Fatigue Coded as Any Contributory Factor
Proportion of Cases
ASRS Data

Anomaly	1985 Sample (N=177)	1987 Sample (N=148)
Alt. Deviation	7/83	1/25
Track/Hdg Dev.	2/18	2/13
Non Adherence	3/8	0/4
Conflict	1/30	2/36
Rwy Trans.	0/3	1/9
Weather	0/4	0/6
Equipment	0/8	0/16
Other	1/23	2/36
Total	14/177	8/145

Table 8
Time of Day
Percent Distribution
ASRS Data

Time	Fatigue Set (N=93)	1985 Sample (N=173*)	1987 Sample (N=145**)	Operations Sample (N=56,298)
0000-0559	13	1	1	2
0600-1159	27	31	35	32
1200-1759	29	47	42	39
1800-2359	31	21	22	28
	100%	100%	100%	101%

* excludes 4 cases, time unknown
** excludes 3 cases, time unknown

Table 9
Fatigue Coded as Any Contributing Factor
By Time of Day
(All ASRS Samples Combined)

	Fatigue A Factor		
Time	Yes	No	% Yes
0000-0559	10	5	67%
0600-1159	26	102	20%
1200-1759	34	136	20%
1800-2359	38	60	39%
Total	108	303*	26%

* Excludes 7 cases, time unknown

Table 10
Smaller Aircraft* as a Percent of All Aircraft
ASRS Data

	Total Aircraft	# Smaller Aircraft	% Smaller
Fatigue Sample	93	37	40%
1985 Sample	177	24	14%
Fatigue cases in '85 Sample	11	5	21%

* Smaller aircraft are those classed as small, light, or medium transport aircraft, with gross takeoff weights of 5,000 - 60,000 pounds

Table 11
Operations and Pilot Deviations by Time of Day

Time	Operations Per Year	Reported Pilot Deviations 1986-1987	Annual Rate per Million Operations
0000-0559	399,000	15	18.8
0600-0759	1,294,000	62	23.9
0800-0959	2,477,000	106	21.4
1000-1159	2,303,000	103	22.4
1200-1359	2,441,000	99	20.3
1400-1559	2,344,000	110	23.5
1600-1759	2,656,000	100	18.8
1800-1959	2,520,000	79	15.7
2000-2159	2,029,000	61	15.0
2200-2359	735,000	22	15.0
Total	19,200,000	757	19.7

Raw data supplied by the Federal Aviation Administration

Figure 1

Weekly Number of Commercial Operations January 16 and July 19, 1986

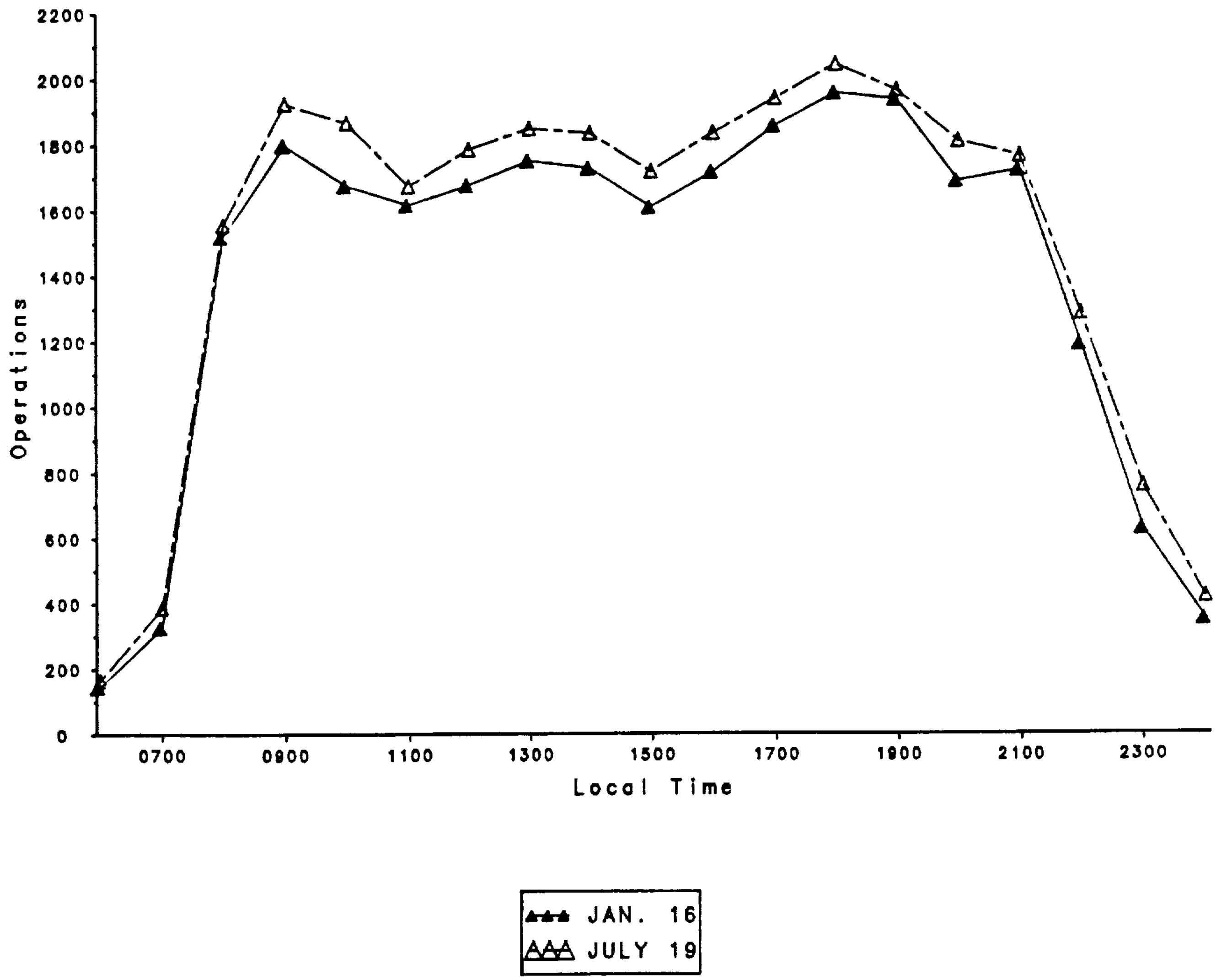


Figure 2

Weekly Number of Arrivals and Departures
Commercial Flights
January 16 and July 19, 1986–87

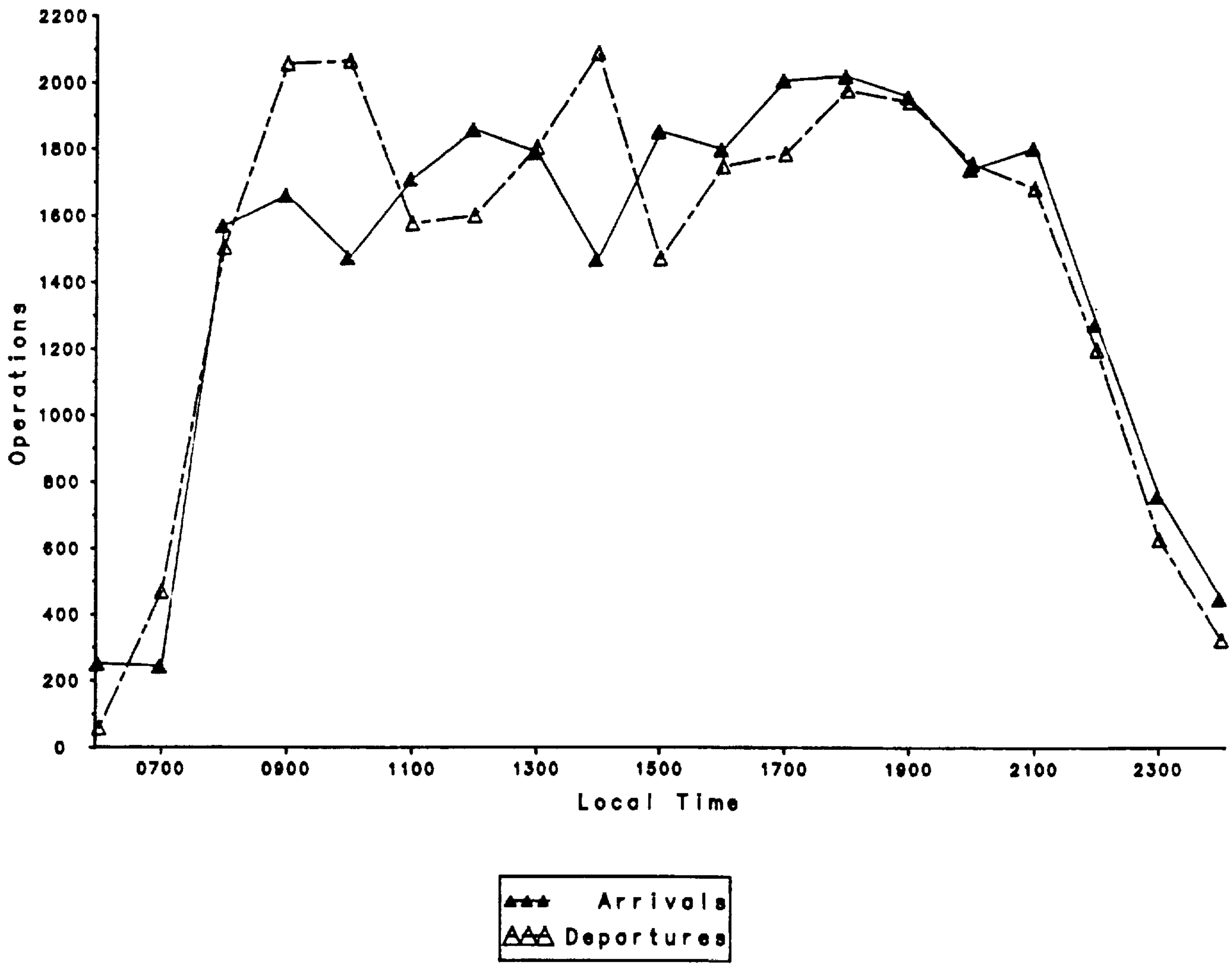


Figure 3

Pilot Deviation Rate by Hour of Day
Air Carriers and Commuters, 1986–87

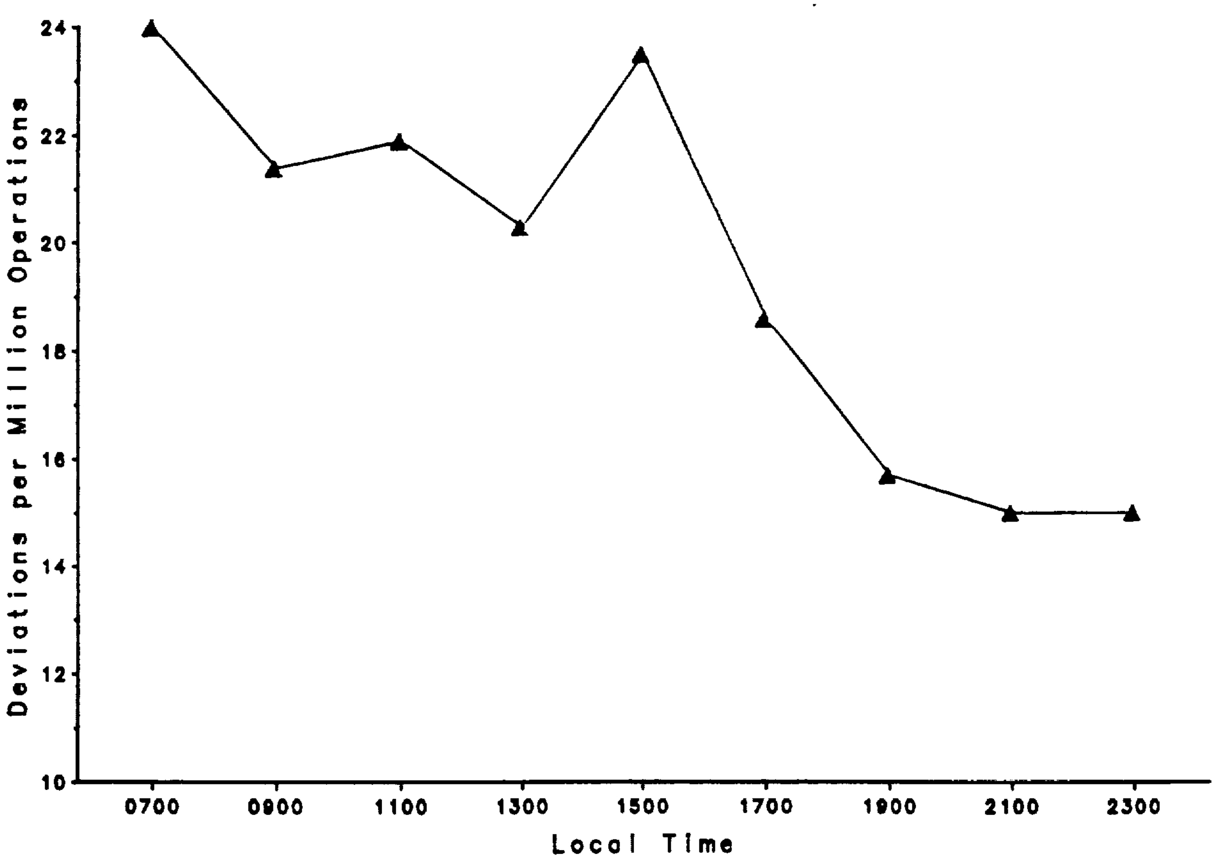


Figure 4

Pilot Deviation Rate by Hour of Day
Altitude and Runway Deviations
Air Carriers and Commuters, 1986–87

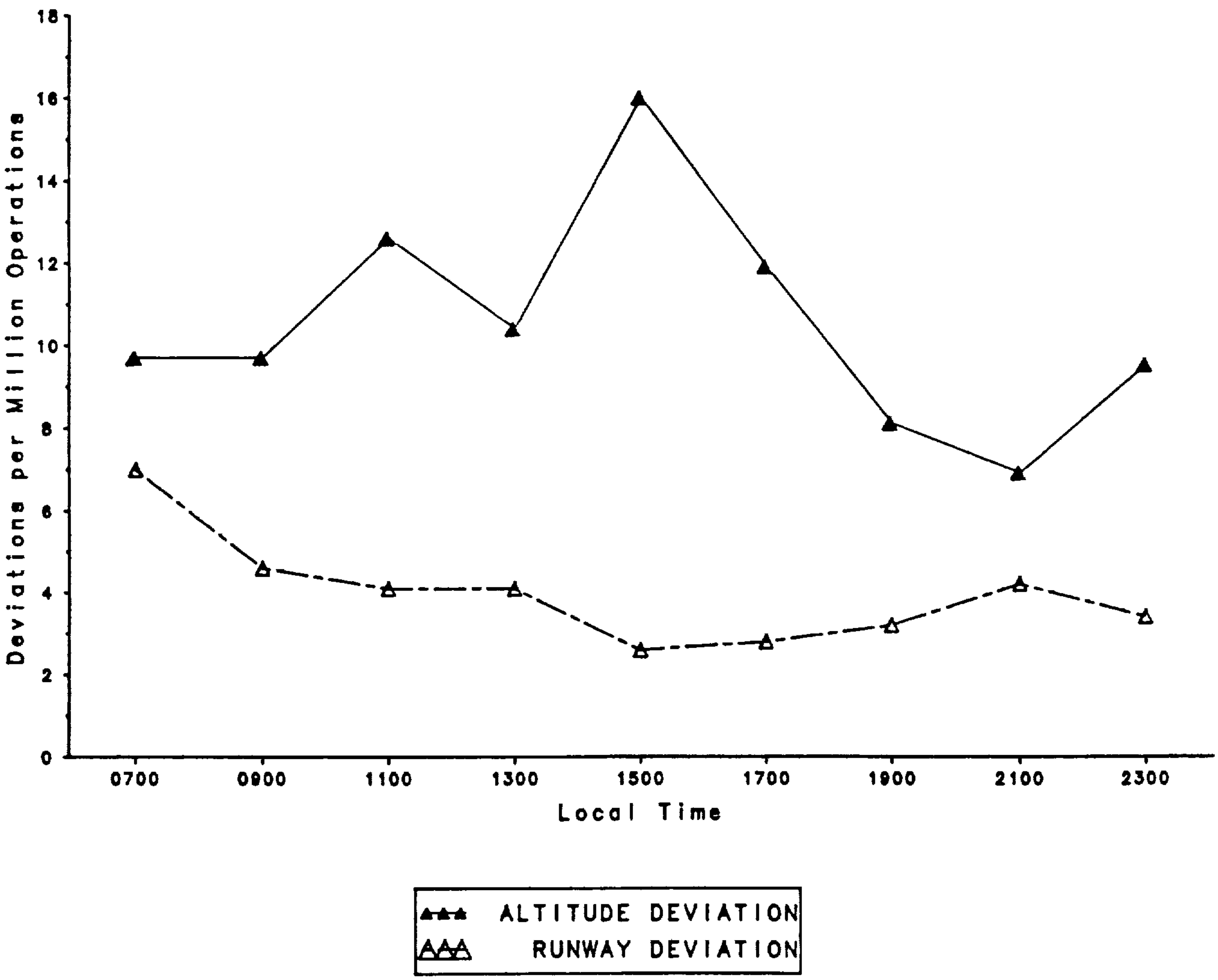
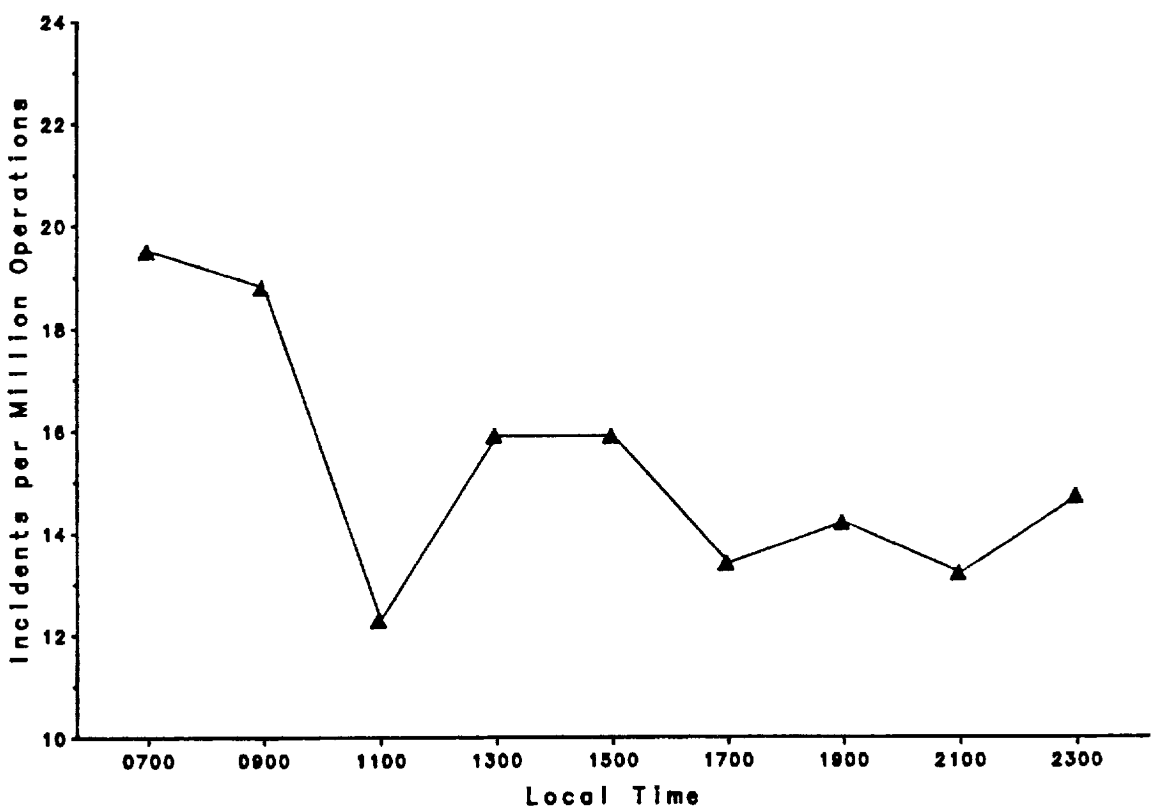


Figure 5

Rate of Pilot–Induced Incidents By Hour of Day



Appendix A

TABLE 1. Anomaly Breakdown by Type of Coding Form**

Type of Anomaly	Abbreviated Forms #	Abbreviated Forms %	Short Forms #	Short Forms %
Acft Equipment Problem/Critical	2	0.0	167	4.2
Acft Equipment Problem/Less Severe	51	3.4	185	4.6
Alt Dev/Excursion from Assigned	785	5.1	86	2.1
Alt Dev/Overshoot on Clb or Des	2431	15.9	148	3.7
Alt Dev/Undershoot on Clb or Des	382	2.5	22	0.5
Alt Dev/Xing Restriction Not Met	619	4.1	53	1.3
Alt-Hdg Rule Deviation	13	0.1	14	0.3
Conflict/Airborne Less Severe	245	1.6	347	8.6
Conflict/Ground Critical	3	0.0	72	1.8
Conflict/Ground Less Severe	32	0.2	72	1.8
Conflict/Nmac	---	---	221	5.5
Controlled Flt Toward Terrain	1	0.0	34	0.8
Erroneous Penetration of Exit Airspace	508	3.3	162	4.0
In-Flt Encounter/Other	15	0.1	20	0.5
In-Flt Encounter/Wx	299	2.0	116	2.9
Less than Legal Separation	84	0.6	288	7.2
Loss of Acft Control	---	---	57	1.4
No Specific Anomaly Occurred	329	2.2	62	1.5
Non Adherence Legal Rqmt/Clnc	3747	24.5	412	10.2
Non Adherence Legal Rqmt/FAR	1059	6.9	345	8.6
Non Adherence Legal Rqmt/Other	69	0.5	37	0.9
Non Adherence Legal Rqmt/Published Proc	485	3.2	154	3.8
Other	1728	11.3	554	13.8
Rwy or Txwy Excursion	34	0.2	24	0.6
Rwy Transgress/Other	225	1.7	115	2.9
Rwy Transgress/Unauth Lndg	252	1.7	23	0.6
Speed Deviation	167	1.1	13	0.3
Track of Hdg Deviation	1138	7.5	174	4.3
Unctrl Arpt Traffic Pattern Deviation	29	0.2	33	0.8
Vfr in Imc	36	0.2	14	0.3
Total*	15263	100.1	4024	99.8

*A single report may record more than one anomaly
** Covers those reports entered in the ASRS database between January 1, and October 7, 1988.

Appendix A

TABLE 2. Air Traffic Incident Breakdown by Type of Coding Form**

Type of Air Traffic Incident	Abbreviated Forms #	Abbreviated Forms %	Short Forms #	Short Forms %
Ambiguous (AMB)	672	8.8	47	2.0
Emergency (EMER)	1	0.0	142	6.1
Flight Assistance (FLTASSIST)	---	0.3	6	0.3
Interfacility Coordination (INTERCOORD)	22	0.0	45	1.9
Intrafacility Coordination (INTRACOORD)	6	0.1	34	1.5
Military Facility Deviation (MILFACDEV)	---	0.0	1	0.0
Miscellaneous (MISC)	997	13.1	588	25.3
Near Midair Collision (NMAC)	---	---	219	9.4
NONE	150	2.0	26	1.1
Operational Deviation (OPDEV)	3	0.0	110	4.7
Operational Error (OPERROR)	1	0.0	266	11.4
Pilot Deviation (PLTDEV)	5775	75.6	833	35.8
Entered Military Airspace (SPILLIN)	8	0.1	4	0.2
Exited Military Airspace (SPILLOUT)	3	0.0	4	0.2
Total*	7638	100.0	2325	99.9

*A single report may record more than one type

Appendix A

TABLE 3. Primary Problem Breakdown by Type of Coding Form*

Type of Primary Problem	Abbreviated Forms #	Abbreviated Forms %	Short Forms #	Short Forms %
Aircraft (ACFT)	166	2.2	247	12.5
Ambiguous (AMB)	708	9.5	86	4.4
Airport (ARPT)	52	0.7	78	3.9
Air Traffic Control (ATC)	225	3.0	479	24.2
Flight Crew (FLC)	6048	81.5	957	48.4
Navigational Aid (NAV)	18	0.2	11	0.6
Other (OTH)	93	1.3	59	3.0
Publication (PUB)	11	0.1	13	0.7
Weather (WX)	100	1.3	47	2.4
Total	7421	99.8	1977	100.1

** Covers those reports entered in the ASRS database between January 1, 1988 and October 7, 1988.

Appendix A

TABLE 4. Reporter Breakdown by Type of Coding Form**

Type of Reporter	Abbreviated Forms #	Abbreviated Forms %	Short Forms #	Short Forms %
Cabin Attendant	8	0.1	7	0.3
Controller	23	0.3	219	10.9
Dispatcher	2	0.0	2	0.1
Vehicle Driver	---	---	1	0.0
Fixed Base Operator	---	---	2	0.1
Flight Crew	7382	99.4	1755	87.7
Flight Service Station Specialist	---	---	1	0.0
Ground Crew	---	---	1	0.0
Observer	3	0.0	6	0.3
Other	2	0.0	3	0.1
Passenger	4	0.1	4	0.2
Total*	7424	99.9	2001	99.7

*A single report may record more than one type

Appendix A

TABLE 5. Time of Occurrence Breakdown by Type of Coding Form*

Time of Occurrence	Abbreviated Forms #	Abbreviated Forms %	Short Forms #	Short Forms %
0001-0600 Local Time (1)	144	1.9	47	2.4
0601-1200 Local Time (2)	2648	35.7	659	33.5
1201-1800 Local Time (3)	2970	40.0	823	41.9
1801-2400 Local Time (4)	1656	22.3	437	22.2
Total	7418	99.9	1966	100.0

**Covers etc.