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Report

FATIGUE AND ASSOCIATED PERFORMANCE DECREMENTS IN AIR TRANSPORT OPERATIONS

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SUMMARY

A study of safety reports submitted to the NASA Aviation Safety Reporting System (ASRS) was conducted to examine the hypothesis that fatigue and associated performance decrements occur in air transport operations, and that these are associated with some combination of the factors: circadian desynchronosis, duty time, pre-duty activity, sleep, work scheduling, workload, and environmental deprivation. The findings of the study are based on a selected sample of reported incidents in which the reporter associated fatigue with the occurrence.

In comparing the fatigue reports with a control set, significant performance decrements were found to exist related to time-of-day, awareness and attention to duty, and - less significantly - final phases of flights. The majority of the fatigue incidents involved such unsafe events as altitude deviations, takeoffs and landings without clearance, and the like. Performance decrements explicitly associated with fatigue are reported infrequently to the Aviation Safety Reporting System and are of a kind differing only in frequency from reports of those occurring in the absence of fatigue. Nevertheless, these fatigue-associated decrements resulted in substantive potentially unsafe aviation conditions. Considerations of duty and sleep are the major factors in the reported fatigue conditions.

INTRODUCTION

This report describes a study to assess the effects of fatigue on air crew performance in transport operations where information from the Aviation

Safety Reporting System (ASRS) data files comprised the principal study resource. NASA requested the study in connection with its larger effort to identify and investigate factors contributing to human error in aviation operations. One facet of that effort is the investigation of the effects of fatigue on flight deck operations. The present study is supportive of that effort.

Aviation operational management has always recognized fatigue as a factor that can adversely affect human performance. Fatigue, however, has eluded rigorous, quantitative definition; as a consequence, the nature of its effects are not completely known (1)*. The minimization of unwanted fatigue effects in organized industry has largely been accomplished by means of work rules. In aviation, these work rules are reviewed frequently and from time to time new ones are postulated (2,3). Consideration is given in the formulation of these rules to new evidence, either operational or scientific, that suggests changes are justified. Such new evidence may be contained in ASRS occurrence files.

Consequently, the purpose of the study described here was to review and analyze incident and occurrence reports submitted to the NASA Aviation Safety Reporting System (ASRS) relating to fatigue. Specifically, the study was to examine the hypotheses that skill fatigue** and associated performance decrements occur, and are associated with some combination of the following factors: (a) circadian desynchronosis, (b) duty time, (c) pre-duty activity, (d) sleep deficit, (e) work scheduling, (f) workload, (g) environmental deprivation, and (h) other factors found pertinent. The examination was to find what sort of confirmation of these hypotheses might exist in ASRS reports and to discover any relationships that might exist between fatigue factors and performance decrements. This report presents the findings of the study.

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*References are listed at the end of the text of the report.

**Skill fatigue - a form of fatigue, as distinguished from mental fatigue, occurring when a continuing task, such as piloting an aircraft, requires complex, coordinated, and accurately timed actions and resulting in a decrement in the skill with which those actions are performed (4).

APPROACH

The data to perform the fatigue study were obtained from the NASA ASRS. A brief description of this program and the analytic procedure follow.

NASA Aviation Safety Reporting System

In response to concerns expressed by the aviation community about identifying and revealing unknown, or not widely known, safety hazards, the Federal Aviation Administration (FAA) implemented a safety reporting program in 1975 (5). To increase the flow of information into the program NASA was asked to manage and operate the safety reporting system. They began operations in April 1976.

The NASA ASRS is a voluntary, confidential reporting system available to pilots, controllers, and others in the National aviation system. Safety reports may be submitted by these persons about situations, occurrences or other matters that they believe may affect air safety. As an inducement to report, FAA offers a limited waiver of disciplinary action to participants who may have inadvertantly violated a Federal Air Regulation.

Reports are submitted to ASRS on a structured form that provides information about aircraft characteristics, weather, experience, type of operation, airspace and air traffic control, etc. Also space is provided for the reporter to describe - in his or her own words - the circumstances of the incident, what happened and why. A copy of the standard report form is in Appendix A.

Upon receipt of a safety report, NASA safety analysts review the report for completeness and criticality of the reported incident. If the analyst believes it appropriate, he may contact the reporter for additional information. When satisfied that the report is as complete as possible, the analyst removes from it the names of the reporter and any other persons or organizations who may have been identified. The analyst then processes the report preparing it for entry into the ASRS data base. After the safety report leaves the analyst's possession there is no opportunity to obtain additional information about the incident. The analyst - to assure the confidentiality of the reporter - never attempts to corroborate the circumstances of the reported incident by contacting other parties.

The computer entry for each safety report contains the fixed field information, the complete text of the reporter's comments, and observations of the analyst. Also, the processed safety report is prepared in such a manner that it may be retrieved from the computer data base by searching on various descriptors or keywords that the analyst has assigned to the report. For example in this study "fatigue" was used as a search term and a number of fixed data fields were screened for the presence of the term. NASA reports (6) present a more complete description of the ASRS data base.

At the time of the study some 20,000 ASRS reports were available for analysis. The next section describes how the "fatigue" set was obtained.

Study Procedure

Figure 1 illustrates the strategy adopted to determine which of the reports should be withdrawn from the ASRS database for review. The study's scope was restricted to consideration of only reports involving air carrier crewmembers.

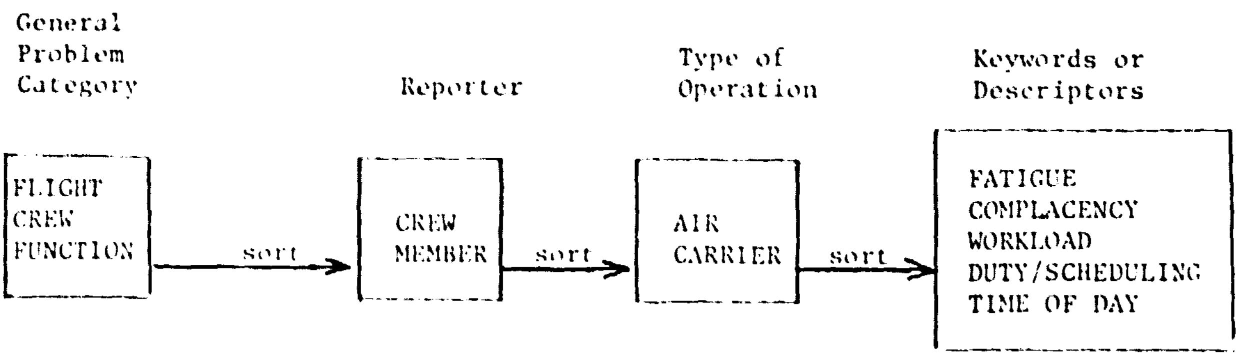

FIGURE 1. SEARCH STRATEGY

Reports resident in the general problem category "flight crew function" contain reports of a deficiency in flight crew performance. The selection of only "crewmember" reports assures that the report describes a pilot, or human, error as witnessed or engaged in; however, reports of performance deficiencies in other aircraft crewmembers may be obtained. The "air carrier" selection assured that the air transport operation criteria would be met. The reports drawn from the database at this point made up the primary test set for the study. The set contained 2006 reports.

The purpose of selecting reports in keyword/descriptor categories other than fatigue was to assure that every reasonable effort had been made to locate all reports involving recognized fatigue, whether or not it was considered the primary factor in the occurrence. The keyword or descriptor categories selected were perceived as having the most direct bearing on the independent variables present in the problem statement. The reports thus obtained were reviewed and a fatigue set established.

To test for operational or behavioral differences that might be more-or-less uniquely associated with fatigue, a comparison set was also selected. This set was taken randomly from the primary test set less the reports identified as the fatigue set.

RESULTS AND DISCUSSION

The test set of 2006 ASRS safety reports represented the population of air transport flight crew error reports. Applying the screening terms fatigue, workload, complacency, duty/scheduling, and time-of-day (midnight to 6:00 a.m.) reduced the test set to 426 reports which were selected for further evaluation. The distribution of reports by screening category is shown in Table 1. Some reports were retrieved under more than one category.

Bartley and Chute (1) suggest that fatigue is a personal experience, i.e., what is fatigue to one may not be to another. Two examples show such to be the case. These are reports of the same incident by two crewmembers. They shared the same bid sequence, but only one suggests fatigue as a factor.

TABLE 1. DISTRIBUTION OF REPORTS BY SCREENING CATEGORY

Screening Category	Number of Reports
Fatigue	71
Workload	225
Complacency	125
Duty/Scheduling	42
Time-of-Day (midnight-0600)	38

"We were as Flight 123-ATL-XYZ 6-FR-79, scheduled to depart ATL at -- --. Clearance was obtained (for Flt 123) by F/O from clearance delivery, i.e., 'Common 4 as filed, squawk 6331'. When we started to taxi we inadvertently reverted to the flight number we had just flown into ATL, Flt 890. We were cleared to 9L as Flt 890. I heard the F/O use Flt 890 in his transmissions but it didn't register at that time. We departed as Flt 890 and departure gave us a new transponder code. When we changed frequencies again the S/O heard us say 890. He said we were 123 and I informed ATL center of the Flt call sign change. They had some problem in identifying our flight but contact was eventually established and we maintained VFR until contact was made. We feel that there are too many flt number changes in a bid sequence period. Use of the aircraft N number could be a solution."

"From ATL to XYZ the proper clearance for Flt 123 was received and copied by the 1st officer. (As filed, Common 4, squawk 6331). Prior to Flt 123, we had flown from ABC to ATL as Flt 890. When the 1st officer contacted ground control he inadvertantly reverted to our previous Flt 890 instead of using Flt 123. We received taxi, takeoff and climb instructions as Flt 890. During climbout, the controller gave us a change of squawk and a change of frequency. I (2nd officer) had just called our company with the out and off times of Flt 123, so when I heard the captain respond to a call for Flt 890 I told him we were 123. The captain then told the center that we were Flt 123 and asked if they had a strip on us which they did. There was some confusion reestablishing radar con-

> tact, so we maintained VFR until radar contact was established. A bid sequence with many flt no. changes and two early morning checkins probably contributed to the confusion over the two flight numbers."

Within the fatigue set seven of the incidents were reported by two or more crewmembers. In four of these fatigue was cited by only one crew member. The fact that crewmembers working under identical conditions and involved in the same incident do not report fatigue as a factor in their performance decrement with consistency reinforces the concept that fatigue frequently is a personal experience and that caution must be exercised in making any generalizations about the presence or absence of fatigue under a given set of conditions.

Accordingly the only reports evaluated in the fatigue set used in this study were those in which fatigue was explicitly stated or implied by the individual reporting. Applying this criterion reduced the set to the 77 unique incidents whose salient features are listed in Appendix B.

In order to examine possible differences between fatigue reports and others, a comparison or "control" set of 100 reports was drawn at random from crewmember reports of flight crew functional problems in air carrier operations, the population from which the fatigue set had been selected. Fatigue reports were, of course, excluded from the comparison set. After screening of these reports to exclude reports in which flight crew behavior was not a part of the problem, and reports that had been submitted by other than an air carrier crew member, 56 reports remained. These were analyzed using the same criteria for the reports as in the fatigue set. Appendix C describes these reports.

Operational Factors

The fatigue and comparison sets were compared to identify operational differences. Recovery factors, for example, were examined from the standpoint of who detected and responded to the flight crew's error. The possibilities are: the flight crew itself, air traffic control (ATC), or no recovery. Examples of no recovery include landing or taking off below minimums or with no ATC clearance. Table 2 shows the results of this analysis.

No significant difference is observed between the fatigue and control sets by chi-square analysis in these categories nor among independent, mutually exclusive sets of data involving weather, flight time during last 90 days, and types of deviations.

TABLE 2. RECOVERY FACTORS COMPARISON

	Flight Crew	ATC	None	Total
Fatigue set	14	36	27	[illegible]
Comparison set	12	29	15	56

The types of deviations reported are presented in Table 3. Although many of these terms are self-explanatory and are consistent with ASRS data base coding procedures, several are not. For example, an altitude deviation could occur based strictly on flight crew action.

> "--- Aircraft cleared over Cash intersection direct Bluf maintain 11,000. Cleared for 9L profile descent shortly after passing Bluf. Descent began to 8000. At 9200 realized chart had been misread."

Or an altitude deviation could occur due to crew misunderstanding of a clearance.

> "--- Our aircraft had been cleared by Oakland Center to descend to and maintain FL240 at Modesto VORTAC. Subsequently we were given an instruction to expect to cross Locke intersection at 10000 ft. Upon reaching FL240 we continued to descend anticipating---"

The former example was classed as an <u>altitude</u> deviation, the latter a <u>clearance</u> deviation.

TABLE 3. TYPES OF DEVIATIONS

Deviation Category	Fatigue Set		Comparison Set	
1. Altitude		25	19	
2. Clearance		27	18	
Take-off without	(2)			(0)
Landing without	(11)			(3)
Other	(14)			(15)
3. Course, Route or Heading		8	4	
4. Runway, Taxi Excursions or Incursions		3	5	
5. Operational		7	5	
6. Technical		5	2	
7. Near Mid-air Collision		1	2	
8. Speed		1	1	
Total		77	56	

A number of reports were classified as operational deviations. These reports include approaches to the wrong runway or airport and landings or take-offs below minimums.

There were five reports in the fatigue set classified as technical deviations. These include the declaration of an emergency to avoid a diversion to load additional fuel, a report of sleeping crewmembers, landing gross weight above certificated levels, operating an aircraft overlooking an MEL restriction, and flying without having flown a required proficiency check ride.

The distribution of deviations by flight phase are shown in Table 4. The category OTHER includes pre-taxi and taxiing incidents.

TABLE 4. COMPARISON OF DEVIATIONS BY FLIGHT PHASE

Test Set	Flight Phase				Total
	Take-off/ Climb	Cruise	Descent/ Approach/ Landing	Other	
Fatigue	11	5	56	5	77
Comparison*	11	10	28	6	55

$X^2 = 7.48 \quad .10 > p > .05$

*One report not coded as to flight phase

Although the differences are not significant*, the deviations within the fatigue set show a tendency to occur more frequently during the descent, approach, and landing flight phases. To be noted is that in 14 of the 16 occurrences during the takeoff, climb, and cruise phases, the reporter commented that the deviations took place towards the end of the duty period.

The time of day of the deviations was considered. The information is coded for six hour intervals, i.e., 0000-0600, 0601-1200, 1201-1800, 1801-2400 where this information was coded. The time represents local time of the incident, not necessarily "body time" of the reporter. The results are shown in Table 5.

The reported deviations occur significantly more frequently between midnight and 0600 hours. Moreover there were only 38 midnight to 0600 hours reports in the study set of 2006 reports. Thirty one percent of these were in the fatigue set.

*The difference might be significant if the reports in the "Other" category are associated with pre-takeoff and post landing phases.

TABLE 5. COMPARISON OF DEVIATIONS BY TIME OF DAY

Test Set	Quarter of Occurrence--Hours Inclusive				
	0001-0600	0601-1200	1201-1800	1801-2400	Total
Fatigue*	12	14	17	14	57
Comparison**	0	11	29	14	54

$X^2 = 12.44 \quad p < .01$

*20 reports not coded as to time of day.

**2 reports not coded as to time of day.

Overall, the results obtained from the analysis of operational factors are not surprising. One would expect a higher proportion of fatigue reports within the time period midnight to 6:00 a.m. "Back-of-the-clock" flying* has been alleged to be more fatiguing than operations flown during other hours of the day. The finding that deviations occur somewhat more frequently during the descent, approach, and landing flight phases should also be expected. If fatigue effects do exist, they should be more often observed at the end of a flight or end of a work day rather than the beginning.

Enabling Factors

Though it is not possible to state with certainty the causes of each of these deviations, it is often possible to list, for a given incident, one or more "enabling factors": elements in the history of the occurrence without which the occurrence probably would not have happened. In particular, it is often possible to state whether a pilot or crew's deviation involved a failure of perception, cognition, or action.

The working definitions used in this study in categorizing these reports are as follows:

*Flying during the hours conventionally considered to be devoted to sleep.

1. Perceptual tasks are activities that involve awareness of: the actual and desired state and position of the airplane, the flight duties associated with that perception, and implementing those duties.
2. Cognitive tasks involve the acquisition, understanding, and effective utilization of information.
3. Manual tasks involve the manipulation of aircraft controls and aircraft systems.

Table 6 shows the comparison of enabling factor distributions between the two sets of reports. The distributions shown between the sets in the table are significantly different. Decrements on monitoring performance occurred considerably more frequently in the fatigue set. Examples of monitoring failures are:

TABLE 6. COMPARISON OF ENABLING FACTORS

Category	Fatigue Set		Comparison Set	
1. Perception		40		15
a. Monitoring	34		7	
b. Distraction	6		8	
2. Cognition		28		26
a. ATC Communication	6		7	
b. Charts, Publications	6		6	
c. Instrument Readings	3		1	
d. Expectations	11		6	
e. Misunderstanding	2		6	
3. Manual		7		15
a. Handling Aircraft	3		9	
b. Setting Instruments	4		6	
4. Other		2		
Total		77		56

$X^2 = 11.84$, $p < .01$

"Enroute from BMS to CLE, we were instructed to maintain airspeed of 300K. We were radar vectored off course of

V-218 south of Windsor VOR. We were further vectored to intercept V-218 and cross Sheff Intersection at 10,000 ft 250K. The first officer was flying, and began the descent at 300K. I was calculating our situation in regards to the crossing restriction and did not notice that the airspeed increased to 320K. Cleveland Center noticed the increase in speed, and asked if we had received the 300K restriction. I replied that we had not. We immediately slowed to 300K and the Center gave us a further airspeed reduction. I informed ATC that with the new airspeed restriction we could not cross Sheff at 10,000 ft. He replied that he could take care of it. I estimate that we were at 320K for no more than one minute. Notice that although we had been maintaining 300K before the descent, I told ATC that we had not received the instructions. Several seconds later, I realized that I had experienced a lapse of attention, but did not wish to further aggravate the situation with a long explanation. I believe that pilot fatigue was directly the cause of my lapse for the one minute, combined with my being pre-occupied with figuring whether or not we were going to be able to comply with the 10,000 ft 250K restriction. The cause of the fatigue was as follows: the trip originated the previous morning at 0617, requiring me to arise at 0330. I estimate that I slept 4 hours. The layover was at the XYZ--- Hotel in St. Paul, Minnesota. The hotel was full of teen-aged hockey players attending a championship playoff. The teen-agers were extremely noisy, requiring many calls from the crew to the front desk, requesting security people to put an end to the noise. The arising time for the return trip was 0500. I estimate that I slept 3 or 4 hours."

"On this series of flights, we were approaching New Orleans Airport (Moisant), which would be our last landing, and number 10 for the day. Approach vectored us to follow acft B in the pattern also being vectored to land. We had the acft B in sight, and reported this to approach, but were still given vectors after reporting. As we were vectored to base, the distance between my A/C and the acft B began to close, we started to slow and began approaching 160 Kts and also the localizer, I asked the first officer to query the controller about going through the localizer, to which the controller responded, takeover the localizer, cleared visual approach. Things were very busy from this point on, to get the A/C ready to land and the X/list complete. A we cleared the runway and called ground control, (who responded cleared to the gate), the F/O, who was not flying, stated, I don't believe we ever talked to the tower. I called the tower by phone and asked to confirm if we had called. He said we did not, but that there was no problem. I don't remember approach turning us over at the outer, as is the normal procedure. Another case of too much to cover in too little time. Also I realize this is my responsibility."

The enabling factor "Cognition (expectations)" also occurs relatively more frequently in the fatigue set. An example follows:

> "Acft A descending for landing was cleared to cross Sicky at 8,000, then descend to and maintain 6,000, by New York ATC. The first officer was flying the aircraft and the captain handling the communications. I observed the first officer descending below 8,000 prior to Sicky and thought perhaps I misunderstood the clearance or he heard something I might have missed. The controller picked up the error with his altitude read out and called it to our attention. The error made in VFR flight conditions. We continued to 6,000. I had not flown over this route in the last 3 or 4 months but had flown it many times previously. As I recall, previous clearances had been cross Sicky 8,000 or below to maintain 6000. It was this clearance for many years. Probably I was mentally programmed for a similar clearance and accepted the first officers departure from the clearance. This was the last leg (15th) of an arduous three day sequence and fatigue was a factor."

Fatigue Factors

A variety of factors were presented as being responsible for the crewmember's perception that fatigue was associated with the reported deviation. These factors are summarized in Table 7.

As stated previously, incidents were included within the fatigue set only if fatigue was either explicitly or implicitly cited. A limitation of the ASRS concept is that the absence of explicit data does not preclude the possibility that a phenomenon of interest existed within the incident reported. For example, within the fatigue set there are reports that involve both long duty periods and long flight times. The possibility certainly exists that time zone traversal or transmeridian flight, occured. In only one report, however, was that information provided explicitly, and insufficient information was provided in the report to permit an appreciation of the

TABLE 7. FATIGUE FACTORS

Category		Number of Citations
1. Pre-duty Activity		3
2. Sleep and Rest		23
a. Adequacy of Rest	7	
b. Disturbed Sleep	16	
3. Duty Period		55
a. No. of Duty Days	8	
b. No. of Duty Hours	26	
c. Flight Hours	8	
d. End of duty period	13	
4. Duty Environment		33
a. Night Operation	11	
b. Weather	6	
c. Workload Low, or From High to Low (Low Stimulus)	12	
d. Discomfort	4	
5. Human Factors (Subjective)		5
a. Tired, Exhausted	5	
6. Workload		18
a. Workload High	4	
b. number of Segments	14	
Total		137

reporter's physiologic state, or the direction of flight. For this reason, a rigorous transformation of the reported fatigue factors into the fatigue factors selected at the initiation of the study (circadian desynchronosis, duty time, pre-duty activity, sleep deficit, work scheduling, workload, and environmental deprivation) is not always possible.

More generally, however, various of the fatigue factor categories may be related to the study postulate. For example, reports within the categories, 'disturbed sleep,' and 'night operations' might well be categorized circadian desynchronosis. Exemplary of reports in these categories are:

> "I was captain on flight from SFO to PHL. We had reported for duty at 0445 pdt. (This was the third day of a four day schedule, in which we have to get up between 3 and 4 a.m.) We flew a ferry to RNO and the flight back to SFO. We departed SFO at 0840. The flight proceeded normally until descent into PHL. We had been cleared to 27,000 feet, direct Lancaster. We then received a clearance to 13,000 feet and were asked to increase our speed as there was traffic behind us. The first officer was flying the airplane and I was working the radio. The first officer levelled off at 23,000 feet, thinking he was at 13,000 feet and I reported level at 13,000 feet,---"

> "Copilot was flying the aircraft on night freighter flight making the Blue Ridge six arrival to DFW, after passing Blue Ridge VOR he turned to an incorrect heading or did not properly select his outbound course of 230 deg. This placed the aircraft off to the left (southeast) of the intended course. Approach control queried if we showed on the correct radial. We replied negative. We show slightly off to the left to which he said you are eight miles off centerline turn right to 250 deg. Although no other aircraft were in the area, situation could have been potentially dangerous during heavy traffic periods. Factors contributing: copilot was relatively new and was not thoroughly familiar with STAR. Captain had switched his VOR to DFW 117.0 in order to have DME to help plan a visual approach and did not properly monitor copilots progress on the 230 deg radial. Fatigue was a big factor. Crew had reported at midnight for a 0130 local dept and had been delayed until 0215 L because of the lack of an aircraft. At the time of occurrence had been on duty seven hours (all night). Fighting sleep was difficult on last leg, so alertness was greatly decreased. As for fatigue - I wish I knew. I took a 3- hour nap the evening prior to departure, but since it is impossible to store up sleep, it is difficult to prepare your body for these occasional all night trips. Crew rest regulations are of no help because the crew rest comes after the fact."

Workload phenomena were revealed in three ways: (1) high workload, (2) low workload, and (3) high workload followed by low workload. These relate back to the original postulates of 'workload' and 'environmental deprivation' (low stimulus). Examples of the three categories follow:

1. High workload. Flt started approach and proceeded beyond outer marker for R-4R while RVR was reported below 4000 ft, with a ship reported to be in the channel. (FAR 121-650). Approach was broken off about 100 ft above minimums, as RVR was still below 4000 ft and ship was still in the channel, though the ground was visible below the acft and the end of the runway was in sight. Executed missed approach and landed on second approach using lower minimums as the ship was no longer reported to be in the channel. This inadvertent, but not in any way dangerous technical violation was caused by crew fatigue, extremely cluttered up approach plate for this rwy (fine print notes, etc.) and conditions of moderate to hvy turbulence and wind shears. Crew was unexpectedly called up for this trip at 0030, departure time was to be 0700. Between being awakened, packing bag, setting alarm clocks, short sleep time was avail. Mgmt refuses to ack that pilots are not computers with a sleep and awake call out. Appeals to FAA have not helped in any way. Small print and cluttered approach plate are fine when you are sitting at a desk, but are not satisfactory under such adverse conditions as changing light conditions, turbulence, having to listen to and ack multiple clearances, and most importantly, fly the airplane. I sincerely believe that we received at least 20 messages (wx and clearances) in about 30 min."

2. High workload to low. "After landing on rwy 5 at BUF, we cleared the runway and began taxiing southwest toward the terminal. A tailwind and light airplane caused speed to pick up rapidly approaching rwy 14-32. By the time the F/O contacted ground control I was about to enter 14-32 at too high a speed to stop. I remembered that about the time we received our landing clearance on rwy 5 the tower also cleared a light plane to land on rwy 32 (I was greatly relieved to see the absence of an aircraft in the approach area of rwy 32). The F/O made contact with ground as we began to cross the runway and with resignation he cleared us to the gate. I think fatigue caused a lapse in procedures and awareness on the part of both of us. It had been a long day and it was almost over, with only one more leg to go. Also, BUF is not as busy an airport as ORD, from where we departed. Our senses were just not as sharp in a more quiet environment than the busy ones we encounter more frequently.

3. Low workload. "Landed without tower clearance, Stapleton Int'l; Airport, Denver Co. Fairly new first officer. Approach control cleared flt in and down unusually smooth and efficient for Denver approach, probably due to late hour and light traffic. One aircraft ahead was on, and clear of runway by the time we were over the OM.

> Approach had cleared us direct to the FAF and then for a visual approach to 26L at Stapleton with the normal call hours and checks. I mistakenly thought the F/O had called the tower at the FAF or on final. As we touched down, Approach asked are you still here? I called the tower by phone and he assured me there was no problem due to no other traffic involved and the late hour. I sure felt dumb letting this get by me."

Of interest is that, in the fatigue set, situations wherein the workload is low occur relatively more frequently than when workload is high. From Table 7 we see that an estimate of the workload level was made in only 16 reports. If we assume that in the remaining 61 reports workload was nominal, then one could infer that fatigue related performance decrements are more frequently associated with situations of nominal or low workload. The notion must rest, unresolved, at this time, since these data do not permit explicit quantification of workload.

An examination of the fatigue reports suggested that further insight might be gained by analyzing along the more restrictive lines of only duty, sleep, or rest and pre-duty considerations. This classification resulted in the assignment of 45, 26, and 6 incidents to these categories, respectively. The individual classifications are noted in Appendix A.

The most notable feature of the six incidents in the rest and pre-duty activity category is that five occurred within the time period 0601 to 1200 hours. The sixth was not coded as to time of occurrence.

The reports in the duty and sleep categories were compared independently with the factors previously described in the control set. The only difference found related to time of day of occurrence. Table 8 shows the distribution of sleep and duty incidents by time of day.

We found that when duty and sleep occurrences were combined significant differences were observed between the fatigue and control sets. When considered separately, the duty subset is not significantly different ($X^2 = 5.56$, $p < .2$).

TABLE 8. TIME OF DAY COMPARISON BY SLEEP AND DUTY FATIGUE FACTORS

Test Set	Quarter of Occurrence-Hours Inclusive			
	0000-0600	0601-1200	1201-1800	1801-2400
Duty*	4	2	14	13
Sleep**	8	7	3	1
Control***	0	11	29	14

* 12 reports not coded as to time of day
** 7 reports not coded as to time of day
*** 2 reports not coded as to time of day

This finding suggests that a fatigue state may be associated independently with either sleep or duty factors. The manifestation of the fatigue state in a crew's behavior remains the same.

The category most frequently cited by crewmembers relates to duty period. About half of these were duty times of 12 hours or more. The following is exemplary of duty period reports.

> "I was flying as first officer aboard lgt acr air lines flight A enroute from Salt Lake City to San Francisco Int'l Airport. Approx XX30 local, a lgt acr B was observed to pass from right to left 90 degrees to our flight path at the same altitude. The distance from us to him at the moment we passed through his jet was estimated by me to be two miles - certainly no nearer than one mile. The other aircraft was acquired visually and no evasive action was judged necessary to avoid collision. Prior to the incident noted above, our aircraft, A, had been cleared by Oakland Center to descend to and maintain FL240 at Modesto VORTAC. Subsequently we were given an instruction to expect to cross Locke Intersection (on the transition to rwy at SFO) at 10000 ft. Upon reaching FL240 during our descent we continued to descend anticipating crossing Locke Intersection at 10000 ft. We had both (captain and first officer) misinterpreted the instruction by center as constituting further clearance to descend to 10000 ft by Locke when in fact, we were

only cleared to 240. At FL230 the above mentioned clearance incident with acft B occurred. Acr B was maintaining FL230 as per ARTC clearance. By the time we had verified our own altitude clearance limit and realized the situation, the two aircraft had passed one another safely with both crews, I assume, swearing among themselves at the crew of the other aircraft and also at ARTC. The weather was broken clouds but clear at flight level. The crew of Acr A had already exceeded the limit of 8 hours of hard flying time in a 24 hour period and had been on duty for approx 12 hours due to actual instrument approaches and holding delays earlier in the day. I, for one, was very fatigued mentally and physically and am sure this contributed to the less than sharp execution of my duties."

FINDINGS AND CONCLUSIONS

Performance decrements which we believe to be related to fatigue have been reported to the Aviation Safety Reporting System. They have resulted in errors and unwanted occurrences in air transport operations. The fatigue-related performance decrements are, however, infrequently reported in relation to the total number of reported air transport crewmember performance decrements.

The factors most frequently cited as being responsible for the fatigue state were duty period and duty environment factors. These were followed by sleep and rest factors. The information presently within the ASRS database does not permit an analysis in depth of the effect of such factors as sleep deprivation, transmeridian flight or circadian desynchronosis.

The types of aircrew deviations that were reported in the fatigue-associated set do not differ from those occurring in a comparison set. However, these deviations appear with somewhat greater frequency during the descent, approach and landing flight phases, and are reported with significantly greater frequency during the first quarter of the day.

Performance decrements associated with awareness and attention were observed significantly more frequently in the fatigue-associated set.

Based on these findings, we conclude:

1. That fatigue-associated performance decrements occur;
2. That fatigue-associated performance decrements can produce potentially hazardous conditions;
3. That only a small fraction of performance decrements reported to ASRS are associated with fatigue by their reporters;
4. That the performance decrements associated with fatigue differ in frequency, but not in kind, from those occurring in its absence;
5. That failures in monitoring tasks are described frequently in fatigue-associated performance decrements reports;
6. That long duty periods, large numbers of flight segments, and disturbed sleep are frequently reported as the reasons for fatigue associated with performance decrements;
7. That the ASRS data do not permit a conclusion as to the effect of circadian desynchronosis on flying performance.

REFERENCES

1. Bartley, S. H., and E. Chute: Fatigue and Impairment in Man. New York, McGraw-Hill Book Company, 1947.

2. Badar, Douglas, Chairman, Report of the Committee on Flight Time Limitations, Civil Aviation Authority, London, 1973.

3. Federal Aviation Administration, Notice No. 78-3, Flight Crewmember Flight and Duty Time Limitations and Rest Requirements, Fed, Reg. V43N39, February 27, 1978.

4. Gartner, W. B., and M. R. Murphy: Pilot Workload and Fatigue: A Critical Survey of Concepts and Assessment Techniques. NASA TN D-8365, 1976.

5. National Aeronautics and Space Administration, Aviation Safety Reporting System, NASA Fact Sheet, No 76-52, 1976.

6. NASA Aviation Safety Reporting System: Third Quarterly Report, NASA TMX-3546, 1977.

APPENDIX A

ASRS REPORT FORM

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APPENDIX A

Form Approved OMB No. [illegible]

IDENTIFICATION STRIP *Please fill in all blanks. This section will be returned to you promptly; no record will be kept.*

TELEPHONE NUMBERS where we may reach you for further details of this occurrence

AREA ____ NO ________ HOURS ________

AREA ____ NO ________ HOURS ________

TYPE OF OCCURRENCE/INCIDENT ________

DATE OF OCCURRENCE ________

TIME (local, 24 hr. clock) ________

NAME ________

ADDRESS ________

(This space reserved for NASA time receipt stamp)

Except for reports of accidents and criminal activities, all identities contained in this report will be removed to assure complete reporter confidentiality.

Please fill in appropriate spaces and circle or check all items which apply to this occurrence or incident.

1. Location (Geographic (including State), airport, runway, ATC facility and sector, navigation aid reference, etc.)

2. Type of operation

SCHEDULED AIR CARRIER		SUPPLEMENTAL CARRIER		CORPORATE AVIATION		MILITARY ARMY	
DOMESTIC OPERATION		CHARTER OPERATION		PERSONAL BUSINESS		NAVY, CG, MC	
INTERNATIONAL OPN		UTILITY OPERATION		PLEASURE FLIGHT		AIR FORCE	
AIR TAXI		AGRICULTURAL OPN		TRAINING FLIGHT		GOVERNMENT	

3. Type of aircraft

FIXED WING: LOW		RETRACTABLE GEAR		RECIPROCATING		GROSS WT. <2500		25,000-50,000	
HIGH WING		CONST. SPEED PROP		TURBOPROP		2500-5000		50,000-100,000	
ROTARY WING		FLAPS		TURBOJET		5000-12,500		100,000-300,000	
NO. OF SEATS		NO. OF ENGINES		WIDE BODY JET		12,500-25,000		OVER 300,000	

4. Second aircraft TYPE (if two aircraft involved)

5. Reported by: PILOT CREWMEMBER CONTROLLER OTHER (specify)

If pilot: TOTAL HOURS HRS. LAST 90 DAYS

6. Light conditions: DAWN DAYLIGHT DUSK NIGHT | 7. Altitude FEET MSL

8. Flight plan: IFR VFR DVFR SVFR NONE | 9. Flight conditions: VFR IFR

10. Flight phase: PREFLIGHT TAXI TAKEOFF CLIMB CRUISE DESCENT HOLDING TRAFFIC PATTERN APPROACH LANDING MISSED APPROACH

11. Airspace: POSITIVE CONTROL AREA (PCA) TERMINAL CONTROL AREA (TCA) ON AIRWAYS AIRPORT TRAFFIC AREA UNCONTROLLED AIRSPACE OTHER CONTROLLED AIRSPACE

12. Air Traffic Control: GROUND TOWER DEPARTURE CENTER APPROACH FSS NONE

13. Weather factors: RESTRICTED VISIBILITY TURBULENCE THUNDERSTORM AIRCRAFT ICING CROSSWIND PRECIPITATION NONE OTHER (specify)

14. (Circle all which you believe apply to this occurrence)

AIRPORT AIR TRAFFIC CONTROL AIR NAVIGATION FACILITY AIRCRAFT FLIGHT CREW AERONAUTICAL PUBLICATION CHARTS OTHER (specify below)

15. NARRATIVE DESCRIPTION: *Please describe the occurrence as clearly and precisely as possible. Include information on: what happened; how was the problem discovered; what actions were taken; was evasive action required; what factors contributed to the situation; why do you believe the situation occurred; your suggestions as to how to prevent a recurrence.*

USE BOTH SIDES OF THE FORM AS REQUIRED

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NASA ARC [illegible]

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

NASA has established an Aviation Safety Reporting System to identify problems in the aviation system which require correction. The program of which this system is a part is described in detail in FAA Advisory Circular 00-46B. Your assistance in informing us about such problems is essential to the success of the program. Please fill out this postage free form as completely as possible, fold it and send it directly to us.

The information you provide on the identity strip will be used only if NASA determines that it is necessary to contact you for further information. THE IDENTITY STRIP WILL BE RETURNED DIRECTLY TO YOU. The return of the identity strip assures your anonymity.

AVIATION SAFETY REPORTING SYSTEM

Section 91.57 of the Federal Aviation Regulations (14 CFR 91.57) prohibits reports filed with NASA from being used for FAA enforcement purposes. This report will not be made available to the FAA for civil penalty or certificate actions for violations of the Federal Air Regulations. Your identity strip, stamped by NASA, is proof that you have submitted a report to the Aviation Safety Reporting System. We can only return the strip to you, however, if you have provided a mailing address. Equally important, we can often obtain additional useful information if our safety analysts can talk with you directly by telephone. For this reason, we have requested telephone numbers where we may reach you. Thank you for your assistance.

NOTE: AIRCRAFT ACCIDENTS SHOULD NOT BE REPORTED ON THIS FORM. SUCH REPORTS SHOULD BE FILED WITH THE NATIONAL TRANSPORTATION SAFETY BOARD AS REQUIRED BY 49CFR830.

15. NARRATIVE DESCRIPTION (continued): *(Use additional sheets if necessary)*

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APPENDIX B

SUMMARY OF FATIGUE RELATED REPORTS

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APPENDIX B

ACCESSION NUMBER	DEVIATION CATEGORY	ENABLING FACTOR	FATIGUE FACTOR	FLIGHT PHASE	RECOVERY FACTOR	WEATHER INVOLVEMENT	TIME OF DAY	FLIGHT TIME, 90 DAYS
1011	ALT	Monitoring	13 Hr Duty	CLB	ATC	No	-	205
2465	ALT	Inst Setting	Low Stimulus, Rebound After	DES	ATC	No	-	-
3032	OPER	Monitoring	11 1/2 Hr Duty	APP	ATC	No	-	150
3078	TECH	[illegible]	11 Hr Duty, 7 Hr Flt Time	OTHER	-	Yes	-	112
* 3688	OPER	Chart	Early AM Awng, Turb, WL	APP	-	Yes	-	150
5135	PROC	Expectation	12 Hr Duty, 6 1/2 Hr Flt Time, Temp	CRS	FLC	No	-	272
5141	ALT	Expectation	Temp, Phys Exhaustion	CLB	ATC	No	-	270
* 6154	ALT	Inst Reading	3 Duty Days, Early AM Awng	DES	ATC	No	-	-
* 6208	CLNC	Monitoring	Night Oper	CLB	ATC	No	-	200
* 6544	CLNC	Monitoring	8 Legs, Early AM Awng	APP	-	No	-	-
6815	OPER	Expectation	12 Hr Duty, IFR Wx	APP	-	Yes	-	150
7071	ALT	Chart	9 Hr Duty, 7 Legs, Wx, Turb	DES	FLC	Yes	-	220
7074	ALT	Monitoring	Tired	DES	FLC	No	-	180
* 7116	TECH	Distraction	Early AM Awng	OTHER	-	No	-	200
* 7347	OPER	Distraction	Early AM Awng	APP	ATC	Yes	-	180
7547	ALT	Chart	12+ Hr Duty, 6 Legs	APP	FLC	No	-	200
* 7578	ALT	Distraction	Tired, Night Oper, Turb	DES	ATC	No	-	210
7863	CLNC	Distraction	Long Day	APP	-	No	-	210
7895	ALT	Misunderstanding	13 Hr Duty, 12 Legs (8 ILS)	DES	FLC	No	-	120
** 8226	ALT	Monitoring	Rest Period	DES	ATC	No	-	200
8918	ALT	Chart	9 Hr Flt Time	DES	FLC	Yes	3	180
8965	CLNC	Expectation	9 Hr Duty, 8th Leg, End of Day	DES	-	No	3	180
** 9142	CLNC	ATC Comm	Rest Period	CLB	ATC	No	2	189
** 9152	CLNC	ATC Comm	Rest Period	DES	FLC	No	2	200
9193	CPS	Monitoring	8:30 Hr Flt Time, 8 Legs (3 ILS)	CRS	ATC	Yes	4	200
9195	ALT	Expectation	3 Duty Days, 15th Leg	DES	ATC	No	3	200
9475	TECH	Distraction	7 Hr Flt Time	APP	-	No	3	200
9791	CLNC	Monitoring	High WL to Low, Routine	APP	-	No	3	210
10588	ALT	Inst Reading	2 High WL Seg with Wx, to Low	DES	ATC	No	4	120
10714	PAT	Handling A/C	3 Duty Days, 54 Hr Duty, 17 Time Zones	LDG	-	Yes	2	-
10763	RTE	Expectation	3 Duty Days, 13 Hr Duty, Food, Vacation	CRS	ATC	No	4	130
* 10449	ALT	Inst Reading	Night Oper	DES	ATC	No	1	150
10619	CLNC	ATC Comm	Long Day, Not Sharp, Routine	LDG	-	No	3	230
10795	CLNC	Monitoring	10+ Hr Duty, Late Hour, Relaxed	APP	-	No	1	160
11156	CLNC	Distraction	10 Days, Last of Day	APP	-	No	3	185
11297	CLNC	Inst Setting	12 Hr Duty, Last of 10 Legs, High WL	APP	-	No	3	180
[illegible]	CPS	Expectation	2 Day Duty, Relaxed	APP	ATC	No	4	210
* 11215/11235	TAXI	Monitoring	Night Oper	LDG	-	No	1	210
11417	ALT	Monitoring	Rest Period, Glare	DES	ATC	Yes	3	170
11579	CLNC	Monitoring	End of Long, Busy Day	TOF	FLC	No	4	180
* 11622	CLNC	Monitoring	3 Hrs Sleep	APP	ATC	Yes	1	160
11661	CLNC	Expectation	11 Hr Duty, 8th IFR Oper	OTHER	ATC	No	4	114
* 11724	PAT	Handling A/C	Night Oper	LDG	FLC	Yes	2	135
11877	ALT	Inst Setting	13 1/2 Hr Duty, Wx	DES	FLC	Yes	1	200
12124/12249	ALT	Inst Setting	2 Duty Days, 12 Hr Duty	DES	ATC	Yes	4	150
12419	CLNC	Expectation	7th Leg of 8 Leg Day	LDG	ATC	No	3	116
* 12650	ALT	Monitoring	3 Duty Days, 4th of 4 Seg, Early AM	CLB	ATC	No	3	210
** 12719	OPER	Expectation	Rest Period, Not Alert	TOF	-	YES	2	210
12342	CLNC	Expectation	End Duty Period	TOF	ATC	No	4	180
* 13716	CLNC	Handling A/C	Night Oper, 2 Seg, Routine, End	APR	-	Yes	2	200
* 13758	ALT	Chart	Tired, Early AM Awng	DES	FLC	No	2	215
14002	PSG	Monitoring	10 2 Hr Fltime, Last of 11 Legs	APR	ATC	Yes	3	200
14058	ALT	Monitoring	9 Hr Duty	DES	ATC	No	3	190
14213	CPS	Misunderstanding	2 Day Duty, Rushed, End of Duty	APR	-	Yes	4	150
14759	ALT	Monitoring	Last Leg of Day, Routine	DES	FLC	No	4	200
* 14474	ALT	Monitoring	12 Hr Duty, Night Oper, 6 Seg	CLB	-	No	2	-
[illegible]	ALT	Monitoring	11 Hr Duty, One Leg to Go, Not Alert	DES	ATC	Yes	4	225
* 14475	CLNC	Monitoring	Night Oper, Low Stimulus	APR	ATC	No	1	10
* 14973-9/[illegible]	CLNC	Monitoring	Early AM Awng	TOF	FLC	No	3	210
* [illegible]	CLNC	Monitoring	Early AM Awng, Sleepy	DES	ATC	No	1	30
[illegible]	OPER	Monitoring	Low Stimulus, Routine	APR	-	No	1	75
* [illegible]	CPS	Monitoring	7 Hr Duty, Night Oper, Sleepy	DES	ATC	No	2	100
* [illegible]	CPS	Monitoring	Early AM Awng, Last Leg, Temp	OTHER	ATC	No	3	75
* [illegible]	CLNC	Monitoring	12 Hr Duty, Early AM Awng, Glare	APR	-	No	4	-
16653	CPS	Monitoring	4 Duty Days, End Duty, 6 wks S/L	CRS	ATC	No	4	100
16735	CLNC	Monitoring	Tired, Relaxed	APR	-	No	2	133
** [illegible]	TECH	-	Duty Time Excl Trip	LDG	-	No	2	29
[illegible]	OPER	Monitoring	4 Duty Days, Routine	APR	FLC	Yes	3	200
* 16647	ALT	Monitoring	3 Hrs Fltime, Early AM Awng	DES	ATC	Yes	1	-
[illegible]	TECH	-	Duty Schedule	CRS	-	No	1	-
* [illegible]	CLNC	ATC Comm	Night Oper	CLB	ATC	No	-	185
[illegible]	ALT	Monitoring	11 Hrs Duty, WL	DES	ATC	No	4	100
[illegible]	CLNC	ATC Comm	12 Hrs Duty, 8 Hr Fltime	DES	-	No	3	[illegible]
* [illegible]	CLNC	ATC Comm	Early AM Awng	OTHER	ATC	Yes	2	150
* [illegible]	[illegible]	Monitoring	Early AM Awng, Inattent	DES	ATC	No	2	90
* [illegible]	CLNC	Monitoring	Early AM Awng, WL	APR	-	Yes	1	50
** [illegible]	CLNC	Monitoring	Pre-Duty Activity,	APR	-	No	2	135

* Sleep
** Rest and pre-duty

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APPENDIX C

SUMMARY OF COMPARISON REPORTS SET

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APPENDIX C

ACCESSION NUMBER	DEVIATION CATEGORY	ENABLING FACTOR	FLIGHT PHASE	RECOVERY FACTOR	WEATHER INVOLVEMENT	TIME OF DAY	FLIGHT TIME, 90 DAYS
8885	CRS	Chart	CRS	ATC	No	3	-
8946	OPER	Chart	TOF	-	Yes	4	-
9014	ALT	Handling A/C	DES	ATC	No	-	300
9043	NMAC	Distraction	APR	FLC	No	4	-
9144	CRS	Inst Setting	-	ATC	No	3	-
9237	TECH	Misunderstanding	APR	ATC	No	3	-
9434	ALT	Handling A/C	CRS	ATC	No	2	190
9635	RWY	Handling A/C	LDG	-	Yes	3	-
9773	CLNC	Distraction	DES	FLC	Yes	3	-
9931	CLNC	Inst Setting	CRS	ATC	No	-	200
10126	CLNC	Misunderstanding	DES	FLC	NO	4	200
10361	CLNC	ATC Comm	CLB	-	No	3	230
10333	NMAC	Monitoring	CRS	FLC	NO	2	235
11555	TAXI	Expectation	OTHER	-	NO	3	77
11896	CLNC	Chart	CRS	-	No	3	210
12011	ALT	Distraction	CLB	ATC	No	2	150
12171	ALT	Inst Setting	DES	ATC	Yes	4	150
12238	CLNC	ATC Comm	CLB	-	No	3	190
12393	ALT	Monitoring	DES	ATC	Yes	4	40
12523	CLNC	ATC Comm	APR	FLC	Yes	3	180
12631	ALT	Inst Setting	DES	ATC	Yes	2	150
12697	ALT	Expectation	DES	FLC	No	3	180
12947	TAXI	Publication	OTHER	-	No	4	-
13127	TAXI	Handling A/C	OTHER	-	No	2	80
13281	TECH	ATC Comm	CRS	-	Yes	3	100
13333	OPER	Handling A/C	APR	-	Yes	3	150
13476	CLNC	ATC Comm	CLB	ATC	No	3	210
13554	ALT	Chart	DES	ATC	No	3	65
13569	CLNC	Expectations	APR	-	No	4	200
13883	ALT	Distraction	DES	-	Yes	3	325
13964	OPER	Monitoring	OTHER	FLC	No	3	180
14293	ALT	Handling A/C	APR	FLC	Yes	2	200
14475	CLNC	Distraction	CLB	-	No	2	240
14597	CLNC	Monitoring	CLB	ATC	No	4	100
15523	CLNC	Inst Setting	CRS	ATC	No	3	130
15739	OPER	Misunderstanding	APR	-	No	4	110
16081	CLNC	Distraction	APR	ATC	No	3	175
16223	OPER	Handling A/C	APR	FLC	Yes	3	210
16325	ALT	Handling A/C	CLB	ATC	Yes	3	170
16491	ALT	Misunderstanding	DES	ATC	No	2	100
17068	ALT	Handling A/C	DES	FLC	Yes	3	200
17327	ALT	Distraction	DES	ATC	No	3	-
17459	CLNC	Monitoring	APR	ATC	Yes	2	125
17549	SFO	ATC Comm	CLB	FLC	No	2	180
17701	ALT	Inst Reading	DES	ATC	No	3	120
17234	CLNC	Misunderstanding	OTHER	FLC	No	4	100
18074	ALT	Monitoring	DES	ATC	No	4	120
18344	RWY	Misunderstanding	TOF	-	Yes	4	130
18473	CLNC	Expectation	APR	ATC	No	3	180
18826	ALT	Inst Setting	CLB	ATC	No	2	203
18916	ALT	Distraction	CRS	ATC	No	3	-
19166	CRS	Expectation	CRS	ATC	Yes	4	110
19360	CRS	Monitoring	CRS	ATC	No	3	165
19443	CLNC	Expectation	CRS	ATC	No	4	110
19563	CLNC	ATC Comm	LDG	ATC	No	3	180
19623	ALT	Chart	DES	ATC	No	3	150

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