"... AND WE WERE TIRED": FATIGUE AND AIRCREW ERRORS

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ABSTRACT
Cooper, White, and Lauber (quoted in ref. 3) analyzed jet-transport accidents worldwide for the period 1968 to 1976 and found more than 60 which breakdowns of the crew-performance and decision-making process played a pivotal role. It is the contention of this paper that the results reported by Cooper et al are related to fatigue and that fatigue is related to sleep deprivation, circadian desynchronosis, and lack of good nutrition. It is further argued, and supporting research is cited, that fatigue does not cause loss of skill in flying the aircraft but may have disastrous effects on judgmental and decision-making functions.

INTRODUCTION
Because of the extreme difficulty in investigating human behavior after an accident, the NASA Aviation Safety Reporting System (ASRS) was brought into being in order to reveal and anticipate unsafe trends and their possible causes. This paper will attempt to demonstrate, based on ASRS-reported information, that the majority of errors made by aircrew members are cognitive errors, not control errors, and that a major contributing factor is fatigue. It is widely accepted that poor crew resource management, distractions, and lack of information transfer contribute to human error. Fatigued pilots are more prone to distraction and seem to suffer from a narrowing of perceptual focus, reserving their attention for issues of aircraft control such as heading, airspeed, and altitude. It is further argued that fatigue is increased by sleep deprivation, circadian desynchronosis, and poor nutrition that may accompany current air carrier scheduling practices.

A request was submitted to the Aviation Safety Reporting System office for a search for all incident reports that mentioned fatigue. These were reviewed and the findings formed the basis for this report. Many of the narratives in these ASRS reports were completed by the phrase "... and we were tired", indicating fatigue was a factor in the incident. Discussions with commercial airline flight-crew members revealed that the scheduling practices of some airlines can result in aircrews receiving less than six hours of sleep, having indefinite eating schedules, and no scheduled breaks. These situations can cause fatigue which can then result in flight crew error. Errors lead to incidents which can lead to accidents if the circumstance and timing coincide.

Graeber (ref. 1) discussed "External Factors Affecting Pilot Decisions" in a paper presented to the Orient Airline Association Annual Flight Safety Seminar in 1987. He stated: "D. A. Norman pointed out that human error can be divided into two types: slips and mistakes. While slips consist of errors of execution, mistakes represent errors of intention. It is primarily this intentional type of error that is usually involved in errors of judgment or variation from established procedures." Figure 2 shows these are two most frequently cited causal factors in flight crew accidents. It is clear from the foregoing statistics that improvements in pilot decision skills potentially offer the largest pay-off in improved safety.

John Lauber, a human factors researcher and NTSB member stated (ref. 2): "... analysis of aviation accidents and incidents reveals that, in general, the human error involved has less to do with switches, knobs and dials, and is more likely to involve fairly high level kinds of behavior -- things like judgment, decision making, cognition, and perception." The purpose of this paper is to explore and report some factors that can influence decision-making and judgmental activities on the flight deck.

APPROACH
The Aviation Safety Reporting System is an incident-reporting system managed by NASA for the FAA. Reports are submitted voluntarily by pilots or controllers for two reasons: first, to report a safety problem; and second, to receive limited immunity from legal actions that may result from the described incident. At the time of this search, 40,286 full-form records had been received since January 1986. The requested incident reports that mentioned flight crew fatigue numbered 281. In 1980, Ames human factors researchers analyzed 2006 reports received since 1976 and found 426 (21.1%) that mentioned factors directly or indirectly related to fatigue. ASRS personnel (ref. 4) state that: "This voluntary system cannot be used to infer frequency or prevalence of problems in the aviation environment. If a large volume of reports can be obtained, however, the probability is high that it provides much useful information concerning the problems and perhaps some useful insights into the causes of those problems." The objective of this paper is to increase the aviation industry awareness about the underlying causes of flawed
decisions pilots are making. The paper will suggest that most errors are cognitive and that cognitive errors are frequently fatigue-induced. It is hoped that both industry and government will respond by initiating appropriate research studies to further define the relevant parameters and develop procedures and regulations that are based on objective and valid findings.

DISCUSSION

Billings and Reynard (ref. 3) examined 22,226 consecutive ASRS Incident reports (fig.3) and stated that “failures of control were rare, suggesting ASRS reporters do not have difficulty making the aircraft do what they want it to do and go where they want it to go. Decision-making and cockpit resource management errors were frequent. . . over 70% of reports are found to involve a failure of information transfer.”

The work of Bartlett (cited by Foushee et al, ref. 4) is commonly cited as one of the major contributions to the literature on complex task fatigue. In this body of work (often referred to as the Cambridge Cockpit Studies) subjects were exposed to tasks which consisted of responding on aircraft-type controls to “changes” in a variety of instruments. Fatigue was manipulated by exposure to these tasks over long periods of time. The findings of these studies seemed to indicate that as alertness declined, progressively larger “deviations” were tolerated before any corrective actions were taken by subjects. It appeared that fatigued subjects were more prone to distraction and seemed to suffer from a narrowing of perceptual focus such that attention was reserved for items of more central importance, such as heading and airspeed indicators. It was further observed that performance on these tasks became more variable, as opposed to less accurate. Moreover, subjective observations indicated that subjects became more irritable with increasing fatigue (“violent” language, etc.).

G. C. Drew (ref. 5) performed “An Experimental Study of Mental Fatigue” in 1940 in an old Spitfire cockpit with the instrument panel designed so that the airmen could follow and obey the general principles of instrument flying. The airmen were required to fly courses which consisted of four maneuvers repeated at given time intervals for the duration of their test. They were also required to monitor temperature and pressure for the various gauges, and correct them if they should change.

The four maneuvers, after stabilizing at a heading from “flying” the simulator, the accurate. Moreover, subjective observations with increasing fatigue (Volent” language, etc.):

Study of Mental Fatigue” in order. The four maneuvers comprised one unit of rate turn to the left through 210 degrees, in that climb of 3500 at 3500 feet/min, and 3500 feet at the rate of 3500 ft/min, (2) a standard of 01 0 degrees and 8500 feet, were:

The failure to use measures of higher-order cognitive functions in Drew’s and other studies ignores the relatively stable effects of fatigue such as increased irritability. For example, the increased irritability associated with fatigue makes it more difficult for crew members to work together effectively. Thus, fatigue effects may not be apparent on individual performance parameters, but significant with respect to group performance. Drew reported that irritability is shown in two ways, first by the constant flow of oaths, and second, by an increasingly violent manipulation of controls. A fatigued pilot starts over-correcting because he is feeling irritable and his over-corrections make him more irritable. For instance, it is well known that the psychophysiological state of a person is directly tied to his or her emotional state. Likewise, it should be expected that the relative emotional states of group members, such as irritability and tiredness, can affect many of the dimensions related to group function. These include leader-subordinate relationships, leadership styles, the personality structures of group members, and communication patterns within the group. It is becoming increasingly apparent that these factors sometimes interact to produce breakdowns in the crew coordination process. See reference 6, for example.

Sleep Quality

A pilots ability to meet duty requirements could conceivably be influenced by his subjective impression of how well he has slept. In general, evidence from the literature (ref. 6) indicates minimal adverse effects of acute or chronic sleep reduction on psychological performance and subjective or objective measures of daytime sleep - unless sleep is restricted to less than about 6 hours a day.
A workshop (ref. 7) on "Pilot Fatigue and Circadian Desynchronosis" was held in 1980 to assist NASA in responding to a Congressional request to determine whether "jet lag" was a concern, was there any valid reason to look at it, and which agency should be doing it. The participants included university, military and other federal agency scientists, pilots, and airline management representatives. It was agreed that extensive literature exists that provides evidence that fatigue is increased (or performance degraded) in association with:

1. Sleep loss or deprivation and alteration of habitual sleep/wake cycles.
2. Circadian desynchronosis associated with time-zone changes and irregularity of work/rest cycles.
3. Long duty hours.
4. Less than optimal nutrition.

**Circadian Desynchronosis**

There is little doubt that the amount of sleep obtainable, even under ideal environmental circumstances, will depend on when sleep is attempted and its relationship to circadian rhythm. If sleep is attempted when the body temperature is rising, the crew member will have considerably more difficulty getting to sleep and, if successful, will usually awaken within a relatively short time. Consequently, the timing of a layover and the adequacy of accommodations for obtaining sleep at any local time of day may be more critical than layover length for assuring proper rest before departure. If sleep loss is inevitable, appropriate sleep time (relative to the biological clock) should be allowed before the next scheduled flight. The types of body-clock problems aircrews are experiencing are illustrated in the following three ASRS reports.

The first report states:
- Somehow we are supposed to shift from a morning to late night schedule in 11 hours layover time... I never get more than 4 hrs sleep, usually less, and the same is true for the captain and flight attendants. I hate to think how many accidents have occurred due to this type of scheduling. Would you put your family on an all night flight wondering how functional the crew is? (92578)

The second report states:
- I completed a minimum crew rest, and the next day my duty day was 13:45 hours. Both my first officer and myself are showing signs of fatigue. I am unable to concentrate, cannot repeat clearances back if they contain more than 2 bits of information, and I cannot even remember my flight number. I have had trouble with fixation on simple tasks. I am going to take some time off without pay because these effects seem to be cumulative and intensifying with each stressful day. Commonly, I have had to go 18 to 24 hours without eating. Attempts to ensure sleep needs and eating patterns is met with counseling and disciplinary action. (123033)

And the third report is as follows:
- Everyone is just too tired to perform. The reason I am writing this is because prior to departing LAX I commented that while the first leg was an unavoidable necessity, adding the second leg by crew schedule is a tired - accident waiting to happen, and foolish economics by the company. The F/O stated that he had been flying this pairing for some time and he had no problem with it, "It's just a matter of getting used to it." On the second leg, I kept a list of the F/O performance as I became aware of it and read it back to him before we left the cockpit in PHL. The flight had been VFR most all of the way from LAX-JFK-PHL, and virtually problem free. The F/O mixed altitude and heading numbers from departure on read back. F/O missed 4 air traffic calls enroute. F/O selected (never used) 18 degree flaps instead of standard 22 degree flaps. F/E caught the error and verified 22 degree flaps were called. F/O had to be told twice to lower gear. F/O did not initially respond to before landing final checklist read by F/E. After landing during taxi in, the F/O performed and answered the after landing checklist, but the radar was left on normal and the transponder was left on until after the secure cockpit checklist was completed and responded to. I caught them on my final review before leaving my seat. I am certain I missed some things too, as well as some of those by the F/O. We all were tired - too tired to fly safely!

The following narrative is representative of the sleep problems aircrews are reporting to NASA's Aviation Safety Reporting System.

- It seems like every time I have 2 long flying days split by a short layover, I have to submit a NASA report for some fatigue related incident. Eight hours behind the door is not long enough. One cannot immediately fall asleep after the completion of a duty period, and that eight hours includes the time to shower and get ready in the morning and ride to the airport. The result is 5 1/2 to 6 hours rest, dangerous! (157426)

**Nutrition**

As the "Pilot Fatigue and Circadian Desynchronosis Workshop" (ref. 7) Indicated, it is accepted knowledge that fatigue is increased by less than optimal nutrition. The next two ASRS narrative reports reflect a common complaint.

- We had been on duty 10 hours and 20 minutes, and we had already logged 8 hours and 5 minutes block-to-block flying time. We had no break in our duty time - not even
And the second report:

- However, I believe that there are several contributing factors. (1) Fatigue: the day of this occurrence was the 3rd day of a 4 day trip. At the time it happened we had just finished 7:37 hrs of flight time. All 4 days required an early wake up. The captain and copilot had both slept badly the night before because of the unusual sleep pattern and outside noise at the hotel. Also contributing to fatigue was the fact that we had no opportunity to eat since the night before. The airline company doesn't feed their own family! (114976)

And, finally, here is a typical, illustrative ASRS report that summarizes the many comments about fatigue that so frequently occurred throughout the many reports reviewed.

- I feel falling asleep at the controls on duty has become almost commonplace. The scheduled flight times are now unrealistic which cause flight crews to have to hustle to try and maintain an unrealistic schedule which then eliminates any break periods - even the AAA recommends a rest after two hours driving and here you have crews flying for 5 straight duty hours without a break. No wonder distractions occur...I feel the cause of this was extreme crew fatigue. Except for a slight hour and a half nap that evening, I had been up for over 24 hrs. I know I felt "punchy" for example, looking out the window for traffic and being oblivious to everything, including traffic...I also saw it in the simple mistakes all 3 of us were making, such as missed radio calls and checklist items. (172229)

The NASA Studies

Congress asked NASA to undertake a comprehensive research program in 1980 to assess whether fatigue-related problems are prevalent in long-haul and short-haul flying. Chidester (ref. 8) conducted a survey of airline pilots to determine normative patterns and individual differences in mood and sleep during short-haul flying operations. The survey revealed that over the course of a typical 2 day trip, pilots experience a decrease in duration and quality of sleep, and a progressively more negative mood. These patterns are very similar to a high fidelity sleep and monitoring activity study performed by Gander and Graeber (ref. 6) which measured the impact of short-haul operations on sleep. The data suggest that commercial short-haul pilots experience sleep loss during 3-day and 4-day duty cycles.

Foushee et al (ref. 3) performed a full mission simulation study that compared the performance of 10 crews who had just completed a 3-day moderate density, short-haul duty cycle with 10 crews who had just had at least 3 days off. The performance of post-duty crews was significantly better than that of pre-duty crews, even though they rated themselves more fatigued. Analyses suggested these results were a function of recently-shared operating experience which facilitated crew coordination. This countered the fatigue that is present at the end of a duty cycle. However, the sleep duration in the pilot survey (ref. 8), as well as the monitor study (ref. 6) was reported to be 6.8 hours. The amount of sleep the pre- and post duty crews had on the simulation (ref. 3) averaged 7.1 hours the two days before the simulation. These studies do not reflect the problems attributed to sleep duration of less than 6 hours currently received by some aircrews. They serve to illustrate the complexity of such studies where experimental control of the relevant variables is of extreme importance particularly in representing the real-world scenarios that are so vividly described in the ASRS reports. It is hoped with the material in this presentation to motivate future studies that more faithfully reconstruct those scenarios.

CONCLUSION

ASRS incident reports indicate some aircrews often receive less than six hours of sleep, experience desynchronosis, and lack of proper nutrition. Research shows fatigue produces psychological and physiological problems that cause cognitive error. Accumulated sleep debt and lack of nutrition contribute to fatigue. If aircrews are not scheduled in a manner that allows enough time to obtain proper sleep, synchronize the body to the appropriate time zones, and receive nutrition, they may not be able to effectively use the automatic decision aids designed to increase the safety of the National Airspace System. Of what use are these aids if the physiologically and psychologically impoverished pilot, in a "white-knuckle" fixation on needle, ball, and airspeed, ignores or cannot utilize these cognitively-oriented technical wonders? As Graeber (ref. 9) has stated: "The experienced airline pilot possesses a unique aviation background against which to judge computer generated alternatives as well as those alternatives which are less obvious to an automated decision aid. Unfortunately, it is precisely the higher level human cognitive skills which are critical for decision making that are most vulnerable to the combined impact of sleep loss, circadian desynchronization, and boredom."

It is hoped this paper will alert the aviation technical community to the need for appropriate research studies to gain the objective data that might lead to a beneficial change in procedures and regulations.

References


**Accident Cause Factors vs Flight Phase**

<table>
<thead>
<tr>
<th>PROBABLE CAUSE</th>
<th>TAXI &amp; TAKEOFF</th>
<th>CLimb &amp; CRUISE</th>
<th>DESCENT &amp; INITIAL APPROACH</th>
<th>FINAL APPROACH</th>
<th>LANDING</th>
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<td><strong>150</strong></td>
<td><strong>102</strong></td>
<td><strong>174</strong></td>
<td><strong>157</strong></td>
<td><strong>688</strong></td>
</tr>
</tbody>
</table>

Worldwide Jet Fleet 1959 - 1983

Figure 1
## Hull Loss Accidents

**Cockpit Crew Cause Factors vs Type of Accident**

**Worldwide Jet Fleet – All Operations – 1959-1983**

<table>
<thead>
<tr>
<th>Cockpit Crew Cause Factors</th>
<th>Type of Accident</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Aborted Takeoff</td>
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<td>Judgement and Technique</td>
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<td>Variance From Established Procedures or Regulations</td>
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<td>Navigational Error Position or Altitude</td>
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<td>Improper System Operation</td>
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<tr>
<td>Improper Flight Control Operation</td>
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<tr>
<td>Failure to See and Avoid Midair Collisions</td>
<td>3</td>
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<tr>
<td>Total</td>
<td>18</td>
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</table>

| Percent of Total                    | 8.6%           | 16.7%              | 14.8%           | 19.6%            | 17.7%              | 7.2%              | 3.3%              | 7.2%             | 3.3%             | 1.0%              | 0.5%            |

**Figure 2**

**Figure 3** Behavioral factors cited in a consecutive sample of ASRS reports