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PILOT PERFORMANCE

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Today, flight plays a very important role in the world. It is used for transportation of people and goods, and aids in the exploration of space as well as playing a major role in the defense of the country. Therefore, every year enormous amounts of time and effort are put into research and production which is aimed at improving planes and other aircraft. Producing aircraft that will fly faster, farther, and on less fuel is a major goal of aerospace researchers all over the world. However, the vehicle itself is not the only important factor in the flight process. Nothing would be possible without the pilots.

For many years, the emphasis has been placed on the aircraft, rather than on those who fly the aircraft. This is largely due to the relative safety of flying. For years everyone has heard that it is much safer to fly in an airplane than it is to drive an automobile, and in comparison the number of aircraft accidents is considerably less than the number of automobile accidents. On the other hand, when a plane crashes, the number of people involved is much greater than the number in a car accident, and the results are much more disastrous. Just in the last few years there have been several major accidents that have shown that flying is not quite as safe as it was thought to be. Sixty-five percent of these accidents are a result of pilot performance decrements, and so it is obvious that there is a need to reduce that figure. Five years ago Congress mandated that a study be done to evaluate pilot performance. This includes workload, circadian rhythms, jet lag, and any other factors which might affect a pilot's performance in the cockpit.

The purpose of this study is to find out when and why the decrements in a pilot's performance occur and how to remedy the situation. Within a flight crew each member brings his/her own characteristics into the cockpit with him/her. The influence of these characteristics combine with conditions of the flight and crew coordination to determine the efficiency of the entire crew, and therefore the safety of the flight.

The majority of air accidents attributed to human factors, result from inadequate knowledge, communication errors, poor pilot judgment, and failure to use available resources, all of which are decrements of pilot performance. However, the major factor contributing to these decrements is pilot fatigue. There are many basic conditions that contribute to pilots' fatigue. 1) Loss of sleep or alterations in sleep patterns. 2) Circadian rhythm desynchronization. 3) Long duty hours. 4) Other human factors: low activity periods, boredom, poor nutrition, and alcohol or drug use to overcome sleeping problems. All of these factors lower the capacity of the pilot, and when the demand on him/her exceeds his/her capacity, the probability of error is greatly increased.

The first and most obvious cause of pilot fatigue is deviations in normal sleep patterns. Night flying or flying through several different time-zones induces situations in which normal sleep patterns cannot be observed. On many overseas flights pilots are required to be alert and at a high work output level at a time when they are normally asleep. Moreover, they may arrive somewhere during daylight hours during which they may have a hard time sleeping. They then may have only a few days to adjust before they must fly the return flight, never allowing their body clocks to adjust, and therefore never sleeping as long or as well as they should. This condition of lack of sleep tends to produce a narrowing of attention and a tendency to commit errors due to short-term memory losses which result from a diversion of attention.

The desynchronization of body clocks is another major cause of pilot fatigue. Many circadian rhythms are present in the human body. These rhythms all represent various physiological and behavioral functions. Normally these rhythms are synchronized, although they are out of phase with one another. These rhythms are controlled by at least one circadian "clock." These clocks are in turn synchronized to the environment, and cannot immediately be reset as the outside environment changes time. Thus, a time-zone traveler finds his/her internal clocks no longer in synchrony with the external ones. And as a result, his/her normal actions such as sleeping are no longer allowed to happen when they should, and when the traveler does sleep, his/her sleep will not be as long or as restful. Slowly these clocks will begin to adjust, but different rhythms adjust at different rates, which results in internal desynchronization within the traveler. Internal and external desynchronization combine to cause fatigue, and in turn, fatigue and sleep loss combine to cause a variety of symptoms: irritability, boredom, headache, and lightheadedness. All of which tend to cause decrements in a pilot's performance, causing disturbances in vigilance and short-term memory.

There are several other causes of pilot fatigue. These include boredom, long duty hours, poor nutrition etc. Earlier studies of pilots have shown that fatigue caused by repeated flights in one day tended to bring on boredom and a lack of concern for precise accuracy on the instruments.

All of these small problems within an individual are greatly intensified when they are present in every member of a crew. The flight crew is susceptible to the effects of group dynamics. Therefore, an emotional upset of one person within the crew greatly affects the function of the entire group. So, it is now becoming obvious that these problems must be fully understood before a solution can be found, and flight can become safer than it already is.

In order to address these issues, find the extent to which this problem exists, and find some solutions to the problem, a comprehensive research program was set up. The program is divided into two parts, a series of field studies and a series of simulated missions. The field studies have as their objectives: (a) to determine the psychological and physiological responses of individual crew members to various flight schedules, with an emphasis placed on documenting circadian physiology, sleep quality and quantity, and fatigue and mood states; (b) to identify relevant individual attributes which may determine, or help predict, the responses of pilots to fatigue and circadian factors; (c) to identify any personal adaptive strategies already being used by the flight crew members; and (d) to identify significant operational factors which affect individual responses to fatigue and circadian factors (as defined by Graeber, Foushee and Lauber in *Dimensions of Flight Crew Performance Decrements: Methodological Implications for Field Research).*

In order to achieve all of these objectives, pilots from all types of flights were needed. Airlines were contacted and schedules were scanned to make sure that all considerations were tested (i.e., early morning, late night, or multiple time-zone crossings). Pilots who fit these schedules were then asked to volunteer as subjects. They were asked to wear a "Vitalog" physiological recorder for a whole flight sequence of between three and twelve days, depending on the nature of the exact study being done (long haul or short haul). The "Vitalog" measures rectal temperature, heart rate, and nondominant wrist activity. Each measurement is made every two minutes. During the flight a NASA observer rides in the jumpseat of the cockpit to record extra data (i.e., weather, equipment troubles, etc.). This observer also helps to enforce subject cooperation and to provide information on crew coordination success.

The subjects are also asked to wear the "Vitalog" before their trip to determine "normal" data, and for up to a week after the trip to observe recovery and return to normalcy. Volunteers are also asked to keep a daily log (fig. 1) which asks for things like wake up time, meals and exercise, and they also fill out a mood chart (fig. 2) every two hours of their waking day. Before the study a background questionnaire helps to tell which pilot attributes this pilot brings into the cockpit with him/her.

The second part of the study is the study of crew performance in an aircraft simulator. This provides a controlled environment in which any chosen circumstance can be induced. The objectives of the simulator studies are: (a) to determine any behavioral and crew performance changes which may be associated with certain types of duty cycles; (b) to determine the operational significance of these changes with regard to flight safety and operational efficiency; (c) to identify possible adaptive strategies that well-coordinated crews may use on the flight deck to cope with the impact of various flight schedules; and (d) to determine whether certain individual attributes are limited to crew coordination and good performance (as defined by Graeber, Foushee and Lauber in *Dimensions of Flight Crew Performance Decrements: Methodological Implications for Field Research).*

Fully qualified flight crews are asked to fly full length simulated missions. These simulations include operational problems in an attempt to test crew interaction and coordination. Each crew is evaluated by a team of trained observers. The observers use computerized data from the simulator of the handling of the aircraft, and video tapes of the crew inside the simulator. These simulations are run on two types of crews. Half of the crews have just come off a long layoff period, and the other half of the crews have just finished one of the flights on the field study schedule. The evaluators are not told the condition of the crew being evaluated and therefore provide totally objective observations. This simulator study used two groups of ten B-737 crews.

There will also be a comprehensive sleep study done during this time. The daily log data from the field study provides some data on sleep though it is mostly subjective. A study among long-haul B-747 crews has been established. This study will have four crews of three members each of four different international carriers. Each subject will be required to spend the first night of the layover in a sleep laboratory. Before the trip the subject will have spent time in the same type of laboratory so that baseline data may be established for comparison with the layover sleep data.

There will also be a posttrip requirement to be compared to the other two sleep situations. Sleep in the laboratories will be much like it would be in a hotel or home or wherever the pilot would otherwise be sleeping.

All of these studies together provide a most extensive crew performance research project. At the conclusion of these studies it is hoped that a much more detailed description of the problem is known. The short-haul section of the study has been completed, though data on the long-haul portion is still being collected. The short-haul study actually used 91 crew members and 47 trips to total 821 flights and 924 flight hours. The study was done in the Eastern United States using DC-9s, B-737s, and B-727s. The results of neither study have been published.

Preliminary interpretation of data and previous studies have found some general facts about fatigue and sleep for pilots. Pilots' sleep patterns tend to be more greatly disturbed on eastbound flights than on westbound flights; though either direction caused activity and heart rate during sleep to increase. The change of time zones always imposes an offset of normal sleeping hours on the traveler and the quality and quantity of sleep are always disturbed. As a result the temperature readings show an actual shift in the phase of the rhythms which govern the body's functions. It has also been observed that the sleep/wake cycle tends to reset faster than the core temperature rhythms.

In general, younger "evening" type pilots adjusted to time shifts better than anyone else, and everyone adjusted better flying in a westward direction than in an eastward one. Even though these results are far from complete and have not yet been analyzed, they are already helping to develop a new understanding of the problem of pilot fatigue, and along with this new understanding come better ideas for a solution. When solutions can be developed and introduced into what is already one of the safest forms of transportation, the results should benefit everyone in the aviation field as well as everyone else who gets on an airplane even once.

REFERENCES

1. Gander, P., Myhre, G., Graeber, R. C., Anderson, H., and Lauber, J. (1985) Crew Factors in Flight Operations: I. Effects of 9-hour Time-Zone Changes on Fatigue and the Circadian Rhythms of Sleep/Wake and Core Temperature. NASA TM-88197, NASA, Washington, DC, December 1985.

2. Graeber, R. C. (ed.) (1986) Crew Factors in Flight Operations: IV. Sleep and Wakefulness in International Aircrews, NASA TM-88231, NASA, Washington, DC, Feb. 1986.

3. Graeber, R. C., Foushee, C., Gander, P., Noga, G. (1984) Circadian Rhythmicity and Fatigue in Flight Operations, Proceedings of the Fourth BOEH International Symposium: Occupational Health in Aviation and Space Work, University of Occupational and Environmental Health, Japan, Oct. 21-23, 1984, 122-129.

4. Graeber, R. C., Jet Lag: The Circadian System in Transition, APA Annual Meeting, Los Angeles, Aug. 24, 1985.

5. Graeber, R. C., Foushee, H. C., and Lauber, J. K. (1984) Dimensions of Flight Crew Performance Decrements: Methodological Implications for Field Research, Breakdown in Human Adaptation to Stress, Vol. I, No. 1, Martinus-Nijhoff Publishers, Boston, 1984.

DAILY LOG

	GMT
WAKE UP (LOCA.)	
SLEEP DURATION (hrs)	Rate Sleep
AWAKENINGS (GMT)	
GET UP	
EXERCISE:	
SHOWER/BATH	
DEPART HOME/LAYOVER	
ON DUTY (LOCA.):	
OFF DUTY (LOCA.):	
ARRIVE HOME/LAYOVER	
NAPS FROM: ____ TO: ____ / FROM: ____ TO: ____	
IN BED	
ASLEEP	

SEGMENTS FLOWN: ____

COMMENTS: ____

DIFFICULTY ARISING? 1 2 3 4 5

HOW RESTED YOU FEEL? 1 2 3 4 5

Rate from least (1) to most (5):

DIFFICULTY FALLING ASLEEP? 1 2 3 4 5

HOW DEEP WAS YOUR SLEEP? 1 2 3 4 5

DAILY LOG

MEAL	TIME	PLACE
B L D S ____	____	____
B L D S ____	____	____
B L D S ____	____	____
B L D S ____	____	____
B L D S ____	____	____

COFFEE/TEA/COLA: ____

BOWEL MOVEMENTS: ____

URINATIONS: ____

NUMBER CIGARETTES: ____(A.M.) ____(P.M.)

MEDICATION: ____ TIME: ____

Did you experience any of the following?

____ HEADACHE	____ BURNING EYES
____ RACING HEART	____ CHILLS
____ CONGESTED NOSE	____ NAUSEA
____ WATERY EYES	____ LIGHT-HEADED
____ FLUSHED FACE	____ FEVERISH
____ DIZZINESS	____ DISORIENTATION
____ CONSTIPATION	____ SWEATING
____ BACK PAIN	____ DIARRHEA
____ SORE THROAT	____ UPSET STOMACH
____ FEELING WEAK	____ SHORT OF BREATH

Other ____

Figure 1.- Daily log.

ORIGINAL PAGE IS
OF POOR QUALITY

Tube ______

MOOD CHECKLIST

MOST DROWSY

GMT ______ Leg/LO ______	not at all	a little	moder-ately	quite a bit	ex-
active	0	1	2	3	4
vigilant	0	1	2	3	4
annoyed	0	1	2	3	4
carefree	0	1	2	3	4
cheerful	0	1	2	3	4
considerate	0	1	2	3	4
defiant	0	1	2	3	4
dependable	0	1	2	3	4
sleepy	0	1	2	3	4
dull	0	1	2	3	4
efficient	0	1	2	3	4
friendly	0	1	2	3	4
full of pep	0	1	2	3	4
grouchy	0	1	2	3	4
happy	0	1	2	3	4
jittery	0	1	2	3	4
kind	0	1	2	3	4
lively	0	1	2	3	4
pleasant	0	1	2	3	4
relaxed	0	1	2	3	4
forgetful	0	1	2	3	4
sluggish	0	1	2	3	4
tense	0	1	2	3	4
clear thinking	0	1	2	3	4
tired	0	1	2	3	4
hard working	0	1	2	3	4

MOST ALERT

Tube ______

MOOD CHECKLIST

MOST DROWSY

GMT ______ Leg/LO ______	not at all	a little	moder-ately	quite a bit	ex-tremely
active	0	1	2	3	4
vigilant	0	1	2	3	4
annoyed	0	1	2	3	4
carefree	0	1	2	3	4
cheerful	0	1	2	3	4
considerate	0	1	2	3	4
defiant	0	1	2	3	4
dependable	0	1	2	3	4
sleepy	0	1	2	3	4
dull	0	1	2	3	4
efficient	0	1	2	3	4
friendly	0	1	2	3	4
full of pep	0	1	2	3	4
grouchy	0	1	2	3	4
happy	0	1	2	3	4
jittery	0	1	2	3	4
kind	0	1	2	3	4
lively	0	1	2	3	4
pleasant	0	1	2	3	4
relaxed	0	1	2	3	4
forgetful	0	1	2	3	4
sluggish	0	1	2	3	4
tense	0	1	2	3	4
clear thinking	0	1	2	3	4
tired	0	1	2	3	4
hard working	0	1	2	3	4

MOST ALERT

Figure 2.- Mood checklist.