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Minimizing Diurnal Desynchronization

Putting common sense and science into flight crew scheduling even on domestic routes can reduce crew fatigue associated with disturbed sleep/wake cycles

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Early in the history of aviation, it was recognized that serious pilot performance degradation could occur as a result of pilot fatigue (Ray, Martin, and Alluisi, 1961). Pilots, their supervisors and managers had a vested interest in maximizing the utilization of individual pilots. For the pilots, the more hours per day that they could work, the amount of money or the number of days off duty would be increased. For management, more hours of utilization per pilot meant that fewer pilots would be required on the payroll. However, this vested economic interest was in conflict with flight safety and with the safety of the traveling public in commercial air transport.

Consequently, government regulatory bodies were established to guide aviation operators in adopting operational policies and practices which could contribute to flight safety and minimize the risks to the traveling public. Regulations were instituted that limited the scheduled flight time of pilots to eight hours in any 24-hour period; 30 hours in a seven-day period; 100 hours in a month; and 1,000 hours in a year. A violation of these regulations could result in fines, suspension or revocation of licenses and operating rights (Slight, 1966).

Although these standards of pilot utilization have been accepted since their inception early in the evolution of commercial aviation, flight time limitations are being questioned as to their adequacy to realistically reflect the work load carried by today's pilots (Wegmann, Conrad and Klein, 1976). In fact, government regulations have remained largely unchanged and unchallenged, while the operating environment of aviation has undergone rapid and radical changes (Siegel, Gerathewohl and Mohler, 1969).

The New Operational Environment

When the pilot utilization rules were first implemented, aviation was primarily a daylight, clear-weather operation by aircraft with speeds of 100 to 150 miles per hour or less. There were few departures outside of daylight hours and most evening departures were back on the ground by 2200 hours. The demand for long-distance, high-speed, 24-hour-a-day operations had not yet developed and the technology did not exist to support it. Pilots rarely found themselves more than 500 miles from their points of departure after one day's flying, and crossing more than one time zone rarely occurred. As a result, pilots were practically never required to fly all night or to arise at 0100 to 0200 on their domicile time to fly a predawn departure from a city three or more time zones from their homes.

The cultural appetite for mobility and the economic need to minimize aircraft downtime caused airlines to schedule around-the-clock operations between major cities (Lederer and Enders, 1987). Including feeder segments and intermediate stops, pilots fly about 20 to 30 percent of their trips between their domicile hours of 2300 and 0600 (Harvey et al, 1969, and Human Engineering Group, 1965).

The increased speed of aircraft has resulted in pilots spending longer hours on duty before they reach their limit of eight hours flying time. The flying time between cities has been decreased by a factor of three in the last 40 years, but the time required to deplane and board passengers, and load and unload cargo has remained relatively fixed. Thus, the ratio of flying time to on-duty time has been steadily dropping. It is quite common for a pilot to be on duty for more than 12 hours and not approach the maximum flying time limit of eight hours; and on multi-leg flights across the United States, duty time may stretch to 14 hours including stopovers and delays. If this duty period occurs during a pilot's normal waking hours, fatigue may not result. However, if these extended duty periods occur during the pilot's normal sleeping hours, serious fatigue and performance problems could result (Webb, Agnew and Williams, 1971).

The Body Gets Confused

Fatigue and performance problems can be linked to changes in the physiological functioning of the body's circadian rhythms (natural sleep/wake cycles). In cases of extended periods of duty time or functioning in a different time zone, the environmental cues used by the body to produce these rhythms are disrupted or rescheduled according to current conditions. Hunger, sleep/wake cycles, body temperature and other physiological rhythms may become desynchronized, depending on the extremity of the situation. This internal dissociation can cause changes in mood, loss of physical and mental efficiency, and add to existing levels of fatigue brought about by normal operating conditions.

In the specific case of performance, Klein and his coworkers (1976) found decrements in simple reaction time, as well as complex sensorimotor tasks. Recovery from a condition of internal desynchronization was found to take from a number of hours to as long as two to three weeks. This recovery time is an important consideration when dealing with flight and cabin crew scheduling.

Following are some examples of domestic two-and three-day trips that have a high fatigue potential due to disrupted diurnal cycles. All times are based upon the pilot's domicile 24-hour clock, and each trip sequence starts and ends at the pilot's home station. The initial duty period of each day starts one hour before the pilot's flight departs; it generally takes one to two hours after landing to get to bed in layover cities.

Table 1 outlines a typical example of desynchronized scheduling of trips. On day one, the pilot reports to home base flight operations at about 2130 for a subsequent 4+50 flight to the layover point. The pilot will generally get to bed at 0500 or 0600. He must sleep long enough to overcome the sleep loss from the incoming flight, and yet be able to return to sleep early enough on a second sleep period, both within 23 hours, to be adequately rested for the maximum legal flying duty day which has a rising time of 0200. To further complicate the situation, the return trip has four landings and take-offs, one of which occurs at the 0900 rush period at one of the world's busiest airports.

Table 2 outlines a schedule which is fatiguing to a pilot who does not sleep well during daylight hours. However, if a pilot can sleep six to eight hours in the afternoon and early evening, this schedule, due to this 23-hour cycle, permits a constant sleep, work and relaxation sequence.

Table 3 outlines a schedule which exemplifies the long duty time within the legal limits of flying time. The crew is on duty more than a 12-hour day which ends at 0500. Since there are three legs to the trip, there is a strong possibility of weather, traffic or mechanical delays which could significantly extend an already long duty period.

The schedule in Table 4 outlines a very early morning departure and a reasonably scheduled flight time duty day. However, the return trip begins just as the pilot would normally retire, and it involves a nearly 10-hour duty day. It is very unlikely that any pilot will report for the second duty period with more than a two- or three-hour nap.

Table 5 outlines a schedule which involves a 2+10 wait between flights in the middle of the night. During this period, the pilot's alertness, level of arousal and performance could be expected to be very degraded for the second leg. He must then sleep twice in the next 22 hours to be adequately rested for the early morning trip home.

The three-day trip in Table 6 outlines a schedule that exemplifies desynchronized all-night and pre-dawn pairings — or combinations — of flights during a duty cycle. In addition, the two final days involve long duty times and several stops with the virtual certainly that the duty days will be extended beyond the schedule time due to delays.

Intensifying the Problem

The less desirable sequences in Tables 1 through 6 are flown by the most inexperienced crews at the bottom of the seniority list. The problem of the inexperienced crew is even more severe in the last five years (Besco, 1987a).

Table 7 outlines an example of a sequence which involves very early morning departures. However, since all three days of the trip are similarly scheduled, the effects of desynchronization are minimized.

Table 8 outlines an example of a desynchronized schedule with the possibility of fatigue effects minimized. After a midnight departure and a short flight, the crew can "sleep out" fatigue for six to nine hours and return home on a relatively short trip with a mid-afternoon departure. Since each day's flying involves only one leg, the risks of multiple approaches, landings and takeoffs are eliminated, as well as the long duty days which accompany multiple legs.

As evidence of desirability, a schedule such as appears in Table 8 likely will be chosen by the most senior and experienced crews, and a schedule such as in Table 7 probably will be flown by crews in the upper half of the seniority brackets.

Comparing Flight Operations

The fatiguing effects of desynchronization on international flight crews has been discussed in detail by many authors (Buck 1976; Graeber 1986; Human Engineering Group, 1965; Nicholson 1972, 1970; Siegel et al., 1961). However, diurnal desynchronization can be more a hazard in domestic operations than in international operations. Some of the primary reasons are that, in domestic operations, more takeoffs and landings are made, increasing exposure to risk (Graeber, 1987), and the approaches are made in a higher density traffic environment. Also, domestic schedules typically have fewer days off between trips. Domestic flight crews generally shift diurnal cycles more frequently and suffer the resultant effects four to seven times per month, while international crews usually shift only one to three times per month. International crews generally fly in a lower work load environment in the cruise portion of their flights, and they are in cruise a longer percentage of the time than are the domestic crews.

The domestic traveling pubic receives more exposure to the risks of diurnal desynchronization simply because there are more departures per day and most domestic flights operate seven days a week. Therefore, domestic diurnal desynchronization problems should receive even more attention, analysis, research and operational planning than they do in international operations.

If diurnal desynchronization is a serious hazard, it could be asked, "Why is not the aviation profession doing something to minimize the problem?" We touched on one of the basic conflicts which detracts from self-adjustment from within the industry. The airlines and the individual pilots have an immediate, or short-term, economic interest in maximizing utilization of pilots. Pilots and airlines have negotiated on-duty time limitations, such as a maximum 14-hour work day; and they have negotiated reduced maximum flight and duty times during normal sleeping hours. These examples contribute to flight safety by reducing fatigue.

Unfortunately, change comes slowly because, I believe, pilots suffer the insecurities shared by all of humankind.

First, medical problems present threats to the pilot. The primary cause behind loss of professional status and earning power in pilots is ill health. Many pilots may experience anxiety by calling attention to anything that would reflect unfavorably on their health or subject them to more intense, or more frequent, medical scrutiny. Some pilots may believe that to admit to any form of insomnia, even in the middle of the afternoon before a late night departure, may be considered an admission of degraded emotional health.

Second, pilots, as a group, have developed respect and satisfaction for their own physical capabilities. Their feelings of self-respect are integrated with the knowledge that they have been selected, trained, promoted and rewarded for their judgment, perceptual motor capacities, physical health and emotional stability. To admit that these attributes can be degraded to the point of reducing flight safety is psychologically difficult for some pilots to admit.

Of course, there is a high redundancy and error tolerance in modern aviation. The cross-checking and monitoring by other crew members, flight controllers and other communicators cause most errors to be corrected gracefully and uneventfully. However, the increased risk levels of fatigue-induced errors could be a significant factor in a serious accident (Besco, 1987b).

One Fix That Worked

An interesting example of how close performance monitoring can reveal the effects of diurnal fatigue was reported by Berry (1970) during the Apollo Program. The best prepared and motivated flight crews in the world made a surprising number of procedural blunders until the program switched to the same 24-hour day for all flight crew members, with everyone on the mission sleeping from midnight to 0700 (Houston, Texas, U.S.) time.

However, airline flight crew scheduling managers look upon their jobs as (1) providing schedules to meet legally defined safety requirements and (2) establishing schedules that minimize the expense to their company. Since legal duty time limitations do not currently address problems caused by diurnal desynchronization, scheduling managers may not feel that they have either the authority or responsibility for solving those problems. Also, additional con-

Day	Wake-up	Report	Takeoff	Landing	Flight Time	Daily Total	On-Duty Hours	Layover Time
				Table 1				
1	1930	2130	2230	0320	4+50	4+50	6+05	23+55
2	0200	0330	0430	0641	2+11			
			0715	0954	2+44			
			1030	1148	1+18			
			1220	1107	1+47	8+00	10+52	
				Table 2				
1	2030	2230	2330	0300	3+30			
			0410	0500	+50			
			0555	0722	1+27	5+47	9+07	13+53
2	2000	2130	2230	0010	1+40			
			0115	0600	4+45	6+25	8+45	
				Table 3				
1	2000	2200	2300	0350	4+50	4+50	6+05	12+40
2	1500	1645	1745	1834	+49			
			2101	2148	+47			
			2255	0445	5+50	7+25	12+15	
				Table 4				
1	0430	0600	0700	0802	1+02			
			0905	1250	3+45	4+47	7+05	10+25
2	2200	2330	0030	0123	+53			
			0330	0533	2+03			
			0610	0910	3+00	5+56	9+55	
				Table 5				
1	2030	2230	2330	0320	3+50			
			0530	0650	1+20	5+10	8+35	21+55
2	0300	0500	0600	1150	5+50	5+50	7+05	
				Table 6				
1	2100	2225	2325	0315	3+50			
			0500	0607	1+07	4+57	7+57	19+53
2	0100	0215	0315	0406	+51			
			0515	0617	1+02			
			0910	1001	+51			
			1030	1130	1+00	3+44	9+30	16+20
3	0230	0405	0505	0537	+32			
			0605	0657	+52			
			0730	0828	+58			
			0855	0931	+36			
			1005	1142	1+37			
			1215	1515	3+00	7+35	11+25	
				Table 7				
1	0400	0545	0645	0748	1+03			
			0815	1115	3+00	4+03	5+45	14+45
2	0100	0215	0315	0406	+51			
			0515	0617	1+02			
			0820	0935	1+15			
			1005	1038	+33	3+41	8+38	16+37
3	0200	0330	0430	0618	1+48			
			0715	1125	4+10	5+58	8+10	
				Table 8				
1	2100	2301	0001	0330	3+29	3+20	4+44	10+00
2	0030	1345	1445	1845	4+00	4+00	5+15	

straints could reduce flexibility in scheduling pilots.

New policies and practices for minimizing the effects of diurnal induced fatigue should be consistent with the operating philosophy underlying all flight operations and flight crew scheduling decisions. The following criteria, generally, have been accepted as a basis for flight crew scheduling philosophy in commercial aviation: safe; legal; economical; pilot preference; and precedent and tradition.

Some specific recommendations are presented for consideration in domestic flight crew scheduling. Some are more applicable to particular types of operations than others; some recommendations will overlap in certain operating environments. However, all these recommendations are consistent with the stated philosophy, and all will contribute to reducing the ill effects of diurnal desynchronization on pilots.

1. Flights that include departures or duty in the off-hours should be given top priority in the selection of trips to be scheduled for subsequent days of the sequence. If an outbound trip results in diurnal desynchronization, the return trips, and any trips on intervening days, should be chosen to minimize the fatiguing effects of desynchronization.

2. Establish duty period limits of eight hours for off-hours trips with a maximum of two scheduled landings. This will minimize the possibility that scheduled on-duty times can be dramatically extended in the middle of the night by creeping delays and schedule slippages.

3. Accomplish scheduling and trip combinations on a system-wide basis to maximize the number of available alternatives. Current constraints include combining trips on freighters only with freighters, passenger trips only with other passenger trips, or certain trips being historically assigned to be flown by crews in certain cities. Such constraints serve only to reduce the options and alternatives available for establishing schedules to minimize the fatigue of desynchronization.

4. Keep the departures on the second and subsequent duty days as close to 24 hours after one another as is possible. This enables crews to establish a consistent sleep, work and relaxation schedule.

5. Pair up the off-hours departures in three- to six-day sequences to minimize the frequency of diurnal shifts.

6. Provide higher economic incentives to pilots on diurnally desynchronized trips to attract more senior crew members to these trips. This will have the effect of uncoupling the double jeopardy of low experience and diurnal fatigue. In addition, pilots who have more personal tolerance for diurnal desynchronization would be attracted to these trips.

7. Maximize the number of evening departures to be flown by the western-most based pilots on the system, so that the effects of staying awake until well past midnight, and approaching dawn, will be minimized.

8. Assign the maximum number of predawn and early morning departures to the eastern-most based crews to minimize past-midnight wake-up calls.

9. Provide standby or reserve crews with at least 24-hour notice for off-hours departures so they can adjust their rest schedules to fit the evening or predawn departures, or dedicate a portion of reserve pilots to off-hours availability.

10. Establish guidelines for the upper limits of “actual” versus “scheduled” flying times and duty hours per duty period. This will reduce economic and organizational pressures on the pilot in spite of creeping and compound delays.

Solution Is Reachable

Domestic flight operations involve significant night flying. This flying can be a serious hazard through diurnally-induced fatigue. With only slight changes in scheduling policies and practices, these ill effects of diurnal desynchronization can be reduced.

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