Fatigue and flight operations

Fatigue is a threat to aviation safety because of the impairments in alertness and performance it creates. "Fatigue" is defined as "a non-pathologic state resulting in a decreased ability to maintain function or workload due to mental or physical stress." The term used to describe a range of experiences from sleepy, or tired, to exhausted. There are two major physiological phenomena that have been demonstrated to create fatigue: sleep loss and circadian rhythm disruption. Fatigue is a normal response to many conditions common to flight operations because of sleep loss, shift work, and long duty cycles. It has significant physiological and performance consequences because it is essential that all flight crew members remain alert and contribute to flight safety by their actions, observations and communications. The only effective treatment for fatigue is adequate sleep (1).

In a National Transportation Safety Board (NTSB) safety study of US major carrier accidents involving flight crew from 1978 to 1990, one finding directly addressed the concern about fatigue. It stated: "Half the captains for whom data were available had been awake for more than 12 hours prior to their accidents. Half the first officers had been awake for more than 11 hours. Crews comprising captains and first officers whose time since awake was above the median for their crew position made more errors overall, and significantly more procedural and tactical decision errors (2)."

An example of fatigue as a probable cause of a US commercial aircraft accident occurred on August 18th, 1993 in Guantanamo Bay, Cuba involving a DC-8. The airplane was destroyed by impact forces and post-accident fire, and the three flight crewmembers sustained serious injuries. Visual meteorological conditions prevailed, and an instrument flight rules plan had been filed. The following is the NTSB summary report:

The airplane collided with terrain approximately 1/4 mi from the approach end of the runway after the captain lost control of the airplane. Flight crew had experienced a disruption of circadian rhythms and sleep loss; had been on duty about 18 hrs and had flown aprx 9 hrs. Capt did not recognize deteriorating flight path and airspeed conditions due to preoccupation with locating strobe light on ground. Strobe light, used as visual reference during approach, inoperative; crew not advised. Repeated callouts by the flight engineer stating slow airspeed conditions went unheeded by the capt. Capt initiated turn from base leg to final at airspeed below calculated vref of 147 kts, and less than 1,000 ft from the shoreline, and he allowed bank angles in excess of 50 deg to develop. Stall warning stick shaker activated 7 secs prior to impact, 5 secs before airplane reached stall speed. No evidence to indicate capt attempted to take proper corrective action at the onset of stick shaker. Operator's management structure and philosophy were insufficient to maintain vigilant oversight and control of the rapidly expanding airline operation.
Probable Cause

The impaired judgement, decision-making, and flying abilities of the captain and flightcrew due to the effects of fatigue; the captain's failure to properly assess the conditions for landing and maintaining vigilant situational awareness of the airplane while maneuvering onto final approach; his failure to prevent the loss of airspeed and avoid a stall while in the steep bank turn; and his failure to execute immediate action to recover from a stall. Additional factors contributing to the cause were the inadequacy of the flight and duty time regulations applied to 14 cfr, part 121, supplemental air carrier, international operations, and the circumstances that resulted in the extended flight/duty hours and fatigue of the flightcrew members. Also contributing were the inadequate crew resource management training and the inadequate training and guidance by the airline, to the flightcrew for operations at special airports, such as guantanamo bay; and the navy's failure to provide a system that would assure that the local tower controller was aware of the inoperative strobe light so as to provide the flightcrew with such information.

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When the sleep patterns of this flight crew were analyzed it was found that the entire flight crew suffered from cumulative sleep loss. They worked under an extended period of continuous wakefulness, and slept at times opposite to their normal circadian sleep patterns. The accident occurred in the afternoon, at the time of their maximum physiological sleepiness (2).

SLEEP AND SLEEP LOSS

Sleep is a vital physiological function. Like food and water, sleep is necessary for survival. Sleepiness results when sleep loss occurs. Like hunger and thirst, sleepiness is the brain's signal that sleep is needed. "Sleep loss" describes the phenomenon of getting less sleep than is needed for maximal waking performance and alertness. If an individual normally needs 8 hours of sleep to feel completely alert, and gets only 6 hours of sleep, 2 hours of sleep loss has been incurred. Sleep loss over successive days accumulates into a "sleep debt." If the individual needing 8 hours of sleep gets only 6 hours a night for 4 nights in a row, an 8 hours sleep debt has been accumulated. The negative effects of one night of sleep loss are compounded by subsequent sleep loss. Sleep loss and the resultant sleepiness can degrade most aspects of human performance. In the laboratory, it has been demonstrated that losing as little as 2 hours of sleep can negatively affect alertness and performance. Performance effects include: degraded judgment, situation awareness, decision-making, and memory; slowed reaction time; lack of concentration; fixation; and worsened mood. Other effects are decreased work efficiency, degraded crew coordination, reduced motivation, decreased vigilance, and increased variability of work performance. The brain is programmed for two periods of maximal sleepiness every 24 hours from about 3 - 5 am and 3 - 5 pm (3).

SYMPTOMS AND EFFECTS OF FATIGUE

Conditions which contribute to fatigue include the time since awake, the amount of time doing the task, sleep debt, and circadian rhythm disruption. As fatigue progresses it is responsible for increased errors of omission, followed by errors of commission, and
microsleep. "Microsleep" is characterized by involuntary sleep lapses lasting from a few seconds to a few minutes (3). For obvious reasons, errors or "short absences" can have significant hazardous consequences in the aviation environment.

Many of the unique characteristics of the flight deck environment make pilots particularly susceptible to fatigue. Contributing aircraft environmental factors include movement restriction, variable air flow, low barometric pressure and humidity, noise, and vibration. In commercial aircraft, hands on flying has been mostly replaced by greater demands on the flight crew to perform vigilant monitoring of multiple flight systems. Research has demonstrated that monotonous vigilance tasks decreased alertness by 80% in one hour (4). This phenomenon is often referred to as "boredom fatigue."

Fatigue and sleepiness may be less evident to a pilot due to stimuli such as noise, physical activity, caffeine, nicotine, thirst, hunger, excitement, and interesting conversation. Sleep-deprived pilots may not notice sleepiness or other fatigue symptoms during preflight and departure flight operations. However once underway and established on altitude and heading, sleepiness and other fatigue symptoms tend to manifest themselves.

When extreme, fatigue can cause uncontrolled and involuntary shutdown of the brain. That is, regardless of motivation, professionalism, or training, an individual who is extremely sleepy can lapse into sleep at any time, despite the potential consequences of inattention. Transportation incidents and accidents, such as the one cited above, provide dramatic examples of this fact.

CIRCADIAN RHYTHMS

"Circadian rhythms" are physiological and behavioral processes, such as sleep/wake, digestion, hormone secretion, and activity, that oscillate on a 25 hour basis. Each rhythm has a peak and a low point during every day/night cycle. Time cues, called "zeitgebers," keep the circadian "clock" set to the appropriate time of day. Common zeitgebers include daylight, meals and work/rest schedules. If the circadian clock is moved to a different schedule, for example when crossing time zones or changing from a day work shift to a night shift, the resulting "sleep phase shift" requires a certain amount of time to adjust to the new schedule. This amount of time depends on the number of hours the schedule is shifted, and the direction of the shift. During this transition, the circadian rhythm disruption or "jet lag" can produce effects similar to those of sleep loss.

Transmeridian flights in excess of three time zones can result in significant circadian rhythm disruption. When flying in a westerly direction the pilot’s day is lengthened. When flying east, against the direction of the sun, the pilot’s day is shortened. Thus the physiological time and local time can vary by several hours. Symptoms of jet lag are usually worse when flying from west to east as the day is artificially shortened. It takes about one day for every time zone crossed to recover from jet lag. When circadian disruption and sleep loss occur together, the adverse effects of each are compounded (3).

CREW REST AND FLYING DUTIES
Scheduling of adequate crew rest needs to take several important factors into consideration. These include time since awake, time on task, type of tasks, extensions of normal duty periods, and cumulative duty times (3).

The "time since awake" is the starting point for fatigue to build. This can be prolonged prior to flying due to the effects of jet lag, early awakening due to disturbances in the sleep environment, the extra time needed to get up check out of a hotel and travel to the airport for flight check in, and delays in getting started preflight procedures including for mechanical problems or weather delays. "Time on task" is the time required to preflight and fly. This is the time from check-in to block-in plus fifteen minutes on the last flight of the day. The "type of tasks" depend on the crew position, type of aircraft, and the nature of the flights. Extensions of normal duty periods can occur from events which prolong the flight longer than scheduled. Such events include delays for en route weather, rerouting due to traffic or, more rarely, diversions. Research on duty period duration suggests that duty periods greater than twelve hours are associated with a higher risk of errors. In determining maximum limits for extended duty periods, consideration needs to be given to all factors which contribute to fatigue including the numbers of legs in the day’s flight plan, whether jet lag is a factor in the crew duty day, and the time since awake. "Cumulative duty times" are most fatiguing when there are consecutive flying days with minimal or near minimal crew rest periods. This can result in sleep debt which requires additional time to overcome (3).

A brief review of US Federal Aviation Administration (FAA) flight time and rest rules for scheduled domestic commercial carriers (US Code Title 14, part 121.471) are as follows:

- **Crewmember total flying time maximum of:**
  - 30 hours in 7 consecutive days
  - 8 hours between required rest periods

- **Rest for scheduled flight during the 24 hours preceding the completion of any flight segment:**
  - 9 hours rest for less than 8 hours scheduled flight time
  - 10 hours rest for 8 hours or more but less than 9 scheduled flight time
  - 11 hours rest for 9 hours or more scheduled flight time

The flight crew duty day starts with check-in, and is considered concluded at block-in plus 15 minutes for that day’s final flight. Rest periods are times when the crewmember is not scheduled for flying duty. These are not periods of restful sleep. Adequate restful sleep, however, must be achievable during these rest periods. In addition to FAA regulations, company rules and practices also influence crew scheduling and rest issues. Company contracts with pilots, scheduling practices for bids and reserve, and productivity demands all play a part in the balance between work requirements and crew rest.
RESTFUL SLEEP REQUIREMENTS

There is considerable variability in individual sleep needs. Some individuals do well with 6 hours sleep per night, yet others need 9 or 10 hours sleep. However, most adults require 8 hours of restful sleep to stay out of sleep debt. With aging there is usually a significant decline in habitual daily sleep due to increased nighttime awakenings. Therefore, in older individuals decreased quality of nighttime sleep can result in increased daytime fatigue, sleepiness, dozing and napping (5) (6). Napping seems to compensate for the loss of quality sleep during nighttime hours, but the need for a mid-day nap may not be compatible with flight duty demands on short haul flights (3). Research has demonstrated that pre-planned cockpit rest has improved in-flight sustained attention and psychomotor response speed (7). Some international airlines have created policies allowing pilots to nap during long haul flights at times of low workloads. Thus far, the US Federal Aviation Regulations have not made reference to planned in-flight crew rest.

Complete recovery from significant sleep debt may not occur after a single sleep period. Usually 2 nights of recovery are required. Eight to 10 hours of recovery sleep per sleep period may be required for most people to achieve effective levels of alertness and performance (8). Obtaining the required sleep time under layover conditions depends on the length of the off duty rest period. Off duty time must be adequate to allow for at least 8 hours of restful sleep per night in order to recover from sleep debt, and therefore the potentially hazardous effects of flying while fatigued.

CONCLUSION AND RECOMMENDATIONS

Pilot fatigue has been shown to be a hazard in commercial flight operations. Many factors contribute to fatigue in the commercial aviation environment. Circadian rhythm disruption, prolonged work schedules, inadequate crew rest, and inadequate restful sleep contribute to the potential for pilot fatigue. When the regulations regarding "rest" are compared to identified requirements for "restful sleep," one can see that adequate restorative rest may not occur. Reviews of federal research activities, hours of service/rest regulations, and airline company scheduling policies are needed to correct existing systemic problems. Enhanced pilot training is also needed to prevent fatigue, and to recognize it when it occurs so that effective countermeasures can be employed (1). Doing so will help insure that pilots fly adequately rested and alert thereby improving flying safety.