Examining fatigue factors in accident investigations essay

A recent international group of scientists identified fatigue as “ the largest identifiable and preventable cause of accidents in transport operations (between 15 and 20% of all accidents), surpassing that of alcohol or drug related incidents in all modes of transportation. Official statistics often underestimate this contribution.

” (Rosekind, 1993). Fatigue engendered by sleep loss and circadian disruption can degrade all aspects of human capability. Significant reductions in operator performance can affect judgment and decision-making, attention, reaction time, alertness, memory, and mood (Rosekind, 1993). These degraded performance factors can increase fatigue-related risks and reduce the operational safety margin. In spite of these well-documented effects, the contributory or causal role that fatigue may play in an accident is often underestimated or potentially ignored. One reason for underestimating its contribution is that there is “ no blood test for fatigue.

” Thorough accident investigations will include an analysis of alcohol and drug factors. If traces of these compounds are discovered, then they are generally identified as causes to the accident. However, no simple, practical or validated “ blood test” for fatigue currently exists. Therefore, to include or exclude fatigue as a cause in an accident requires the evaluation of two specific aspects of the accident. First, was there identifiable fatigue factors present at the time of the accident? Second, if fatigue factors were present, did fatigue-related performance decrements contribute to or cause the accident? This paper will outline a systematic approach to examine the role of fatigue factors in an accident investigation. First, four specific physiological factors that can create fatigue will be described, including scientific data regarding their relevance.

Second, there will be discussion of how to examine whether fatigue–related performance changes played a contributory or causal role in an accident. Third, to demonstrate the application of this approach in an actual accident investigation, the crash of a DC-8 in Guantanamo Bay, Cuba will be used as a model analysis. Scientific literature indicates that there are four physiological factors that are known to underlie fatigue and are relevant to an accident investigation (Rosekind & Graber). These four fatigue factors are: sleep, continuous hours of wakefulness, circadian rhythms, and sleep disorders. Each of these physiological factors will be described and their operational relevance discussed for their potential role in an accident.

On average, human adults physiologically require about 8 hours of sleep for optimal waking performance and alertness (Kryler, 1994). Sleep loss can be considered in two ways: acute and cumulative. Acute sleep loss involves the total amount of sleep obtained in a 24-hour period. An average person that obtains only 5 hours of sleep one night has an acute sleep loss of 3 hours. Sleep loss that occurs over several days builds into a cumulative sleep debt.

An average person that obtains only 5 hours of sleep for 3 consecutive nights has a cumulative sleep debt of 9 hours. Recovery from a cumulative sleep debt typically involves more deep sleep and not an hour-for-hour payback of lost sleep that requires extended sleep. Generally, two nights of usual sleep, at a person's regular bedtime, can reduce the cumulative sleep debt to 0.

Calculating an individual's acute sleep loss or cumulative sleep debt should be based on the person's usual sleep requirement and pattern.

A scientific review found that two hours of sleep loss can result in " impairment of performance and levels of alertness"` (Kryler, 1994). How long an individual operator remains awake is another physiological factor that can affect performance and alertness. The physiological complement to sleep is the subsequent number of hours of continuous wakefulness. Shift work studies examining different duty lengths (e.

g. , 8 vs. 10 vs. 12 hours) have provided mixed findings. At 12 hours, some studies have shown significant decreases in performance and alertness and increases in errors and injuries (Monk, 1994). NTSB aviation accident data have shown an increased risk beyond 12 hours (Graeber, 1994).

At 16 hours of work, a national occupational-injury database demonstrated a progressive increase three times the accident/injury rate at 9 hours (Kryler, 1994). Other studies have shown that performance decrements associated with 17 hours or longer of prolonged wakefulness can approximate the changes typical of alcohol consumption (Graeber, 1994). Generally, performance and alertness can be maintained up to 12 hours of wakefulness. Data suggest that 16 or 17 hours of continuous wakefulness can be associated with significantly reduced performance and alertness (Kryler, 1994). The changes associated with periods of 12 to 16 hours of continuous wakefulness are not well defined.

Another major physiological determinant of waking performance and alertness is the internal circadian clock. Located in the suprachiasmatic nucleus (SCN) of the hypothalamus, the circadian clock controls the timing of physiological activity, performance, alertness, and mood (Roth, 1994). Daily, the circadian clock is programmed for its lowest point at around 3 am to 5 am. This is the period of lowest activity across physiological systems and human functioning. Performance reductions can occur in a larger window from about 12 am to 6 am. A second programmed period of sleepiness occurs at about 3 pm to 5 pm.

These windows of circadian low are associated with decreased performance, alertness, and mood and are especially relevant in an accident investigation when a critical phase of operation occurs during one of them. However, just operating during these periods is associated with physiological changes that reduce performance and alertness. Almost 90 different sleep disorders exist and are described in a diagnostic classification system (Wake up America, 1993). The primary presenting complaint for many of these disorders is excessive sleepiness. There are a broad range of physiological and psychological causes for these sleep disorders and the individual sufferer might be unaware of its existence. Most of these sleep disorders can be diagnosed and treated successfully by accredited sleep medicine specialists.

This factor is a consideration because an operator may have a sleep disorder that predisposes the individual for excessive sleepiness. Altered circadian rhythms (e. g. , shift work, time zone crossings) and other factors could further exacerbate the preexisting sleepiness (Wake up America, 1993). One example sleep disorder is sleep apnea, a condition in which an individual has breathing pauses throughout sleep.

This causes waking sleepiness and performance decrements, as well as other related health problems (Rosekind & Graber). Studies of individuals with sleep apnea have shown up to a 7 times increased risk for car accidents (Rosekind & Graber). Sleep disorders, such as sleep apnea, put individuals at increased risk for sleepiness and potential performance reductions. In an accident investigation, each of these four fatigue factors should be evaluated to determine whether they were present at the time of the accident. The information regarding these factors should be obtained from a variety of sources whenever possible.

For example, the sleep/wake history might be collected from the individual operator involved in the accident, from family members or coworkers. This involves obtaining information about usual sleep patterns and habitual bed times and then specifics for the period prior to the accident. Usually, a minimum of a 72-hour period before an accident should be examined. Depending on circumstances, it may be necessary to review a longer period of time. The continuous hours of wakefulness can be determined from an individual’s report and operating information. The circadian factor can be straightforward and would identify whether a critical phase of operation or significant performance requirement occurred during a window of circadian low.

A sleep medicine specialist may be needed to determine whether an individual had a sleep disorder at the time of an accident. It is important to consider the sources of information used to examine these fatigue factors. Typically, self-report data is obtained by interviewing an operator about circumstances prior to an accident. Therefore it is important to obtain information about these fatigue factors from a variety of sources whenever possible.

Once the information related to these factors is obtained and analyzed, it should be determined whether each one was present at the time of the accident and to what extent. The first step, as previously described, is to determine whether to include or exclude fatigue factors as present at the time of the accident. If fatigue factors were present, the second step is to determine whether fatigue-related performance decrements were contributory or causal in the accident. Fatigue created by sleep loss and circadian disruption can decrease waking performance, vigilance, and mood. These decrements are known to affect errors, accidents, and safety (Graeber, 1994).

The basic question is whether fatigue-related decrements can be linked to performance that contributed to or caused the accident. Obviously, this aspect of the determination relies heavily on the specifics of the accident. In 1993, the National Transportation Safety Board (NTSB) investigated a DC-8 accident at Guantanamo Bay, Cuba. At the request of the NTSB investigators, members of the NASA Fatigue Countermeasures Program examined the fatigue factors related to the accident (Rosekind, 1993).

A full NTSB report on the accident has been published and includes an appendix on the analysis of the fatigue factors by the NASA Group. The four fatigue factors were analyzed for the AIA Flight Crew involved in an aviation accident that occurred at Guantanamo Bay, Cuba on August 18, 1993. The data analyzed were taken from the NTSB Human Performance Investigator's

Factual Report, the Operations Group Chairman's Factual Report, and the Flight 808 Crew Statements. When there were discrepancies among the sources, conservative estimates and averages were used. The sleep/wake histories for the Flight Crew of AIA Flight 808 prior to the accident at Guantanamo Bay on August 18, 1993 at about 1656 EDT are presented in Figure 1(Rosekind & Graber).

Figure 1 This figure provides an opportunity to examine the amount of sleep and wakefulness over the three days leading up to the accident. The white bars indicate the duty periods and individual black lines show specific takeoff and landing activities during the duty periods. A single horizontal bar for each flight crewmember shows the sleep (black) and wakefulness (shaded) over the period leading up to the accident. The Captain was then awake for 23.

hours until the accident occurred at Guantanamo Bay. This 23. 5-hour period included an all-night duty period after which the Captain was released from duty. However, he was called back to operate Flight 808 prior to his return home, and therefore was continuously awake until the accident.

The First Officer was then awake for 19 hours until the accident occurred at Guantanamo Bay. This 19-hour period included an all-night duty period after which the First Officer was released from duty. However, he was called back to operate Flight 808 prior to his leaving the airport, and therefore was continuously awake until the accident. The Flight Engineer was then awake for 21 hours until the accident occurred at Guantanamo Bay (Rosekind & Graber). The data presented demonstrated that the entire crew had experienced sleep loss, extended periods of continuous wakefulness, and circadian disruption. Given the sleep and circadian history of the entire flight crew, it is clear fatigue was present.

However, to determine how fatigue may have contributed to or caused the accident, one would have to determine whether performance and behavioral changes associated with fatigue played a role in the accident. Several sources of data were available for examination to provide specific information regarding flight crew performance and actions before the accident. The transcript of the cockpit voice recorder (CVR) was made available at the NTSB hearing on this accident, and the Captain provided testimony at the hearing (Rosekind & Graber). Based on an analysis of this data, four fatigue-related performance changes were identified that contributed to or were causal in this accident. These factors are Degraded Judgment and Decision-Making, Cognitive Fixation, Poor Communication/Coordination, Reduced Reaction Time (Gander, 1993).

The CVR transcript provides information about flight crew performance, decisions, and responses leading up to the accident at Guantanamo Bay. One piece of information is related to the decision to use runway 10. Two of the crewmembers, including the Captain (the pilot flying), had never flown into Guantanamo Bay; the First Officer had only flown into Guantanamo Bay years before in small military jets (Rosekind & Graber). The crew acknowledged that it was a difficult airport with special considerations. The plan had been to use the straightforward approach available on runway 28.

With essentially no discussion, the Captain decided to change plans and use runway 10, which requires a more severe maneuver to complete the landing. By all reports, the Captain was lauded for his airmanship and good judgment, especially in emergency and landing procedures. Therefore, for an experienced Captain to make a sudden decision to change runways, with no prior experience at a special airport, with minimal crew discussion, indicates a degraded decision-making process. In this situation, fatigue may have affected the crew's decision-making in the following ways; they did not consider important information (i. e.

, their unfamiliarity with the airport, their level of fatigue), their lack of discussion about the decision to change runways, and misreading of potential outcomes. In this case, the entire flight crew, all of whom were affected by the fatigue factors previously outlined, shared the decision-making process (Kryer, 1994). Another piece of information from the CVR was the Captain's fixation on finding a strobe light that was a landing cue (Rosekind & Graber). In the transcript, the Captain makes seven references to finding the strobe light. During the critical period leading up to the accident, the Captain displayed an overwhelming focus and concern to locate the strobe light. This cognitive fixation on the strobe light, to the exclusion of other critical information, is another potential fatigue affect on performance.

It would fit laboratory research that demonstrates that this effect can result from sleep loss (Monk, 1994). Also evident from the CVR was the Captain's disregard of critical information just prior to the accident. While the Captain was fixated on locating the strobe light and was making multiple references to its location, the other crewmembers questioned whether they were going to successfully make the landing. The Captain did not acknowledge the question, certainly did not process the potential implications of the question, and finally disregarded the critical information to continue his search for the strobe light (Rosekind & Graber). While the transcript reveals that words were expressed, the crew actions indicate poor communication and coordination of efforts.

Another piece of information from the CVR was the response to the stall warning when the operation was clearly in trouble. Several pilots reviewed the CVR transcript and commented on how slowly the Captain and crew responded to the stall warning prior to the accident. The warning is intended to provide a window for immediate response and an opportunity to recover the aircraft (Rosekind & Graber). An experienced pilot will have been trained to immediately respond to the stall warning with an automatic response. However, fatigue can degrade reaction time and psychomotor responses.

Therefore, the Captain and crew appear to have been slow to respond to the stall warning as a consequence of the prior sleep loss, circadian disruption, and extended period of continuous wakefulness (Graeber, 1994). There are several other instances from the CVR that suggest the presence of fatigue but are subtler. For example, there appears to have been excessive checking of information (e. g. , were waypoints entered radio frequencies). These more subtle occurrences may also reflect decreased memory and mental functioning but are less clearly defined than the previous four examples from the CVR.

The level of performance demonstrated by the Captain is below that normally expected of a Captain with his level of experience. However, the Captain’s aviation record does not suggest that he was a substandard pilot. The Captain’s airmanship was praised from several sources. Therefore, some factor must have interfered with his performance on this flight.

Also note that some of the CVR performance decrements identified above were also Crew Resource Management (CRM) failures (Rosekind, 1993). This further supports the data that the entire crew, not just the Captain, was affected by fatigue at the time of the accident. Another piece of information that became available at the NTSB hearing was the Captain’s testimony. Perhaps the most telling statement was in response to the question about how he felt just prior to the accident and he said, “ lethargic and indifferent” (Rosekind & Graber).

Individuals use a variety of words to express their state associated with sleep loss and circadian disruption, for example, ‘ fatigued,’ ‘ tired,’ ‘ sleepy,’ and ‘ lethargic. Also, controlled laboratory studies of sleep deprivation have shown that individuals will increase their effort to perform, though their performance is degraded, and they become indifferent to the outcome. The Captain’s report of being “ lethargic and indifferent” in the period leading up to the accident is quite consistent with the typical effects of sleep and circadian disruption. This paper outlines a systematic approach to examine fatigue factors in an accident investigation. Four core fatigue factors are identified and a summary of their physiological and operational relevance is provided.

Determining whether these fatigue factors can be included or excluded is the first step of analysis. Next, it is critical to examine whether fatigue-related changes can be linked to actions that caused or contributed to an accident. This analytical approach was applied to the investigation of a DC-8 accident at Guantanamo Bay, Cuba. Based on its analysis, the NTSB determined “ that the probable causes of this accident were the impaired judgment, decision-making, and flying abilities of the captain and flightcrew due to the effects of fatigue” (Roth, 1994). Based on their findings, the NTSB made the following recommendations related to fatigue. Require that flight time accumulated in noncommercial “ tail end” ferry flights be included in total flight and duty time accrued; expedite the review and upgrade of Flight/Duty Time Limitations of the Federal Aviation Regulations to ensure that they incorporate the results of the latest research on fatigue and sleep issues; and require U.

S. air carriers to include, as part of pilot training, a program to educate pilots about the detrimental effects of fatigue, and strategies for avoiding fatigue and countering its effects. It is important to acknowledge the limitations of human physiology regarding sleep, circadian rhythms, and fatigue. The flight crewmembers involved in this accident were clearly professional, well trained, experienced, and highly motivated to perform their best. As humans, there are limitations to performance that are purely a reflection of physiological capabilities and can be independent of training, motivation, and experience.