National Transportation Safety Board

Washington, D.C. 20594

Safety Recommendation

Date: June 12, 2008

In reply refer to: A-08-44 and -45
A-06-11 (Superseded)

The Honorable Robert A. Sturgell
Acting Administrator
Federal Aviation Administration
Washington, D.C. 20591

Background

Several aviation accidents and incidents that have occurred in the past few years[1] have highlighted the dangers of human fatigue within airline operations, the need to address factors related to issues of both company policies and crewmember responsibilities, and the continued need for changes to flight and duty time regulations to effectively mitigate the dangers of fatigue to aviation operations. Four of these events are discussed in detail below.

On October 19, 2004, about 1937 central daylight time, a BAE Systems BAE-J3201, Corporate Airlines flight 5966, struck trees on final approach and crashed short of the airport in Kirksville, Missouri. Both pilots and 11 passengers were killed, and 2 passengers received serious injuries. The pilots had been executing a nonprecision approach at night in instrument conditions at the end of a 14.5-hour-long duty day for which they reported to duty early and during which they had conducted five previous landings in poor visibility. The National Transportation Safety Board determined that the probable cause of the accident was the pilots' failure to follow established procedures and properly conduct the approach and to adhere to established division of duties. The Safety Board also determined that the pilots' "fatigue likely contributed to their degraded performance." The Board recommended that the Federal Aviation Administration (FAA) modify and simplify flight crew hours-of-service regulations and require operators to incorporate information about fatigue in their training programs.[2]

[1] The National Transportation Safety Board has a long history of recommending improvements in aviation fatigue, which will be discussed later in this letter.

[2] As a result of the Kirksville investigation, the Safety Board issued Safety Recommendations A-06-10 and -11. Safety Recommendation A-06-10 asked the FAA to modify and simplify the flight crew hours-of-service regulations to take into consideration factors such as length of duty day, starting time, workload, and other factors shown by recent research, scientific evidence, and current industry experience to affect crew alertness. Safety Recommendation A-06-10 is on the Safety Board's Most Wanted List of Transportation Safety Improvements. (Safety Recommendation A-06-10 superseded Safety Recommendation A-99-45, which had superseded Safety Recommendation I-89-3.) Safety Recommendation A-06-11 asked the FAA to require 14 *Code of Federal*

On February 18, 2007, about 1506 eastern standard time, Delta Connection flight 6448, an Embraer ERJ-170, N862RW, operated by Shuttle America, Inc., was landing on runway 28 at Cleveland-Hopkins International Airport, Cleveland, Ohio, during snow conditions when it overran the end of the runway, contacted an instrument landing system antenna, and struck an airport perimeter fence. The airplane was substantially damaged, but all 71 passengers, 2 pilots, and 2 flight attendants deplaned without serious injury. The Safety Board determined that the probable cause of the accident was the failure of the flight crew to execute a missed approach when visual cues for the runway were not distinct and identifiable and that factors contributing to the accident included both the captain's fatigue and shortcomings in the company's attendance policy.[3]

The investigation revealed that the captain had been suffering from intermittent insomnia during the months preceding the accident. During postaccident interviews, the captain stated that he felt rested when he accepted the accident trip on the previous day but that he was unable to sleep overnight and, at the time of the accident, had been awake for 31 of the preceding 32 hours. He added that, before the flight, he warned the other flight crewmembers that he was tired but that he did not advise the company of his fatigue or remove himself from duty because he believed that the company would have terminated his employment. As a result, he placed himself, his crew, and his passengers in a dangerous situation that could have been avoided. The investigation confirmed that Shuttle America had an official attendance policy that allowed pilots to remove themselves from duty because of fatigue but that, in practice, the administration of this policy did not permit flight crewmembers to call in as fatigued without fear of reprisals. The Safety Board recommended an industry effort to develop and implement a "best practices" attendance policy that would allow flight crewmembers to decline assignments or remove themselves from duty if they were impaired by a lack of sleep.

On April 12, 2007, a Bombardier/Canadair CL600-2B19 regional jet operated as Pinnacle Airlines flight 4712 ran off the runway after landing at Cherry Capital Airport, Traverse City, Michigan, during snow conditions. None of the 49 passengers (including 3 lap-held infants) and 3 crewmembers received injuries, and the aircraft was substantially damaged. The investigation revealed that the flight crew, consisting of a check airman and a newly hired pilot, executed an instrument landing system approach without first computing a required landing distance assessment that would have indicated that the runway length was inadequate for the prevailing weather. The pilots were at the end of a 14-hour-long duty day in which they had conducted four previous landings in challenging weather, and the cockpit voice recorder recorded the crew yawning and making multiple comments about being fatigued before they initiated the approach. The Safety Board determined that the flight crew's "poor decision-making likely reflected the

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Regulations (CFR) Part 121 and 135 operators to incorporate fatigue-related information similar to that being developed by the Department of Transportation Operator Fatigue Management Program into their initial and recurrent training programs; such training should address the detrimental effects of fatigue and include strategies for avoiding fatigue and countering its effects. For further information, see National Transportation Safety Board, *Crash Short of the Runway, Corporate Airlines Flight 5966, British Aerospace BAE-J3201, Kirksville, Missouri, October 19, 2004*, Aircraft Accident Report NTSB/AAR-06/01 (Washington, DC: NTSB, 2006).

[3] National Transportation Safety Board, *Runway Overrun During Landing, Shuttle America, Flight 6448, Embraer ERJ-170, Cleveland, Ohio, February 18, 2007*, Aircraft Accident Report NTSB/AAR-08/01 (Washington, DC: NTSB, 2008).

effects of fatigue produced by a long, demanding duty day and, for the captain, the duties associated with check airman functions."

On February 13, 2008, Go! flight 1002, a Bombardier CL-600 regional jet operated by Mesa Airlines, flew past its destination airport, General Lyman Field (ITO), Hilo, Hawaii. About 0940 Hawaiian standard time, as the flight was crossing the island of Maui, the flight crew failed to respond to an air traffic control (ATC) instruction. Over the next 18 minutes, ATC repeatedly attempted to contact flight 1002 as it flew over Maui, crossed the big island of Hawaii, and headed southeast over the Pacific Ocean. About 0958, after traveling 26 nautical miles beyond the destination airport, the flight crew contacted ATC and subsequently complied with ATC instructions directing the flight back to ITO. The airplane landed without incident, and all 3 flight crewmembers and 40 passengers on board deplaned safely. Although the investigation is ongoing, it has revealed that both pilots unintentionally fell asleep during cruise flight. A review of flight crew scheduling information revealed that the crew had been on duty for less than 4.5 hours at the time of the incident. The pilots were on the third day of a trip schedule that involved repeated early start times and demanding sequences of numerous short flight segments. The Safety Board received information that, after the incident, one of the pilots was diagnosed with obstructive sleep apnea, which, without medical treatment, is associated with reduced sleep quality, excessive daytime fatigue, and, in severe cases, cognitive dysfunction.[4]

Safety Board Fatigue-Related Safety Recommendation History and Support of Industry Initiatives

The Safety Board has had longstanding concerns about human fatigue causing or contributing to aviation accidents and/or incidents. Since 1972, the Board has issued 115 human fatigue-related safety recommendations in all modes of transportation, including 32 recommendations addressing fatigue in the aviation environment and 4 intermodal recommendations. The Board has included safety recommendations related to human fatigue in transport operations on its annual Most Wanted List of Transportation Safety Improvements since its inception in 1990.[5] The Most Wanted List currently has seven aviation fatigue-related

[4] L. Ferini-Strambi, C. Baietto, et. al., "Cognitive Dysfunction in Patients with Obstructive Sleep Apnea (OSA): Partial Reversibility After Continuous Positive Airway Pressure (CPAP)," *Brain Research Bulletin*, Vol. 61 (2003): 87-92.

[5] In addition to Safety Recommendation A-06-10, two other aircraft flight crew fatigue-related safety recommendations are on the Safety Board's Most Wanted List of Transportation Safety Improvements. Safety Recommendation A-94-194 asked the FAA to revise the federal aviation regulations contained in 14 CFR Part 135 to require that pilot flight time accumulated in all company flying conducted after revenue operations, such as training and check flights, ferry flights, and repositioning flights, be included in the crewmember's total flight time accrued during revenue operations. Safety Recommendation A-95-113 asked the FAA to finalize the review of current flight and duty time regulations and revise the regulations, as necessary, within 1 year to ensure that flight and duty time limitations consider research findings in fatigue and sleep issues. The recommendation also stated that the new regulations should prohibit air carriers from assigning flight crews to flights conducted under 14 CFR Part 91, unless the flight crews meet the flight and duty time limitations under 14 CFR Part 121 or other appropriate regulations. For further information, see (a) National Transportation Safety Board, *Commuter Airlines Safety Study*, NTSB/SS-94/02 (Washington, DC: NTSB, 1994) and (b) National Transportation Safety Board, *Uncontrolled Collision with Terrain, Air Transport International, Douglas DC-8-63, N782AL, Kansas City International Airport, Kansas City, Missouri, February 16, 1995,* Aircraft Accident Report NTSB/AAR-95/06 (Washington, DC: NTSB, 1995).

recommendations: three concerning flight crews, three concerning air traffic controllers, and one concerning maintenance personnel. The Board has also addressed specific fatigue issues associated with the Corporate Airlines, Delta Connection, and Pinnacle accidents and numerous other accidents;[6] however, as evidenced by the Go! event, fatigue-related incidents continue to occur.

Many of the fatigue-related safety recommendations concerned flight and duty time regulations, which provide a necessary set of not-to-exceed limits for any fatigue management efforts. Although scheduling practices and flight and duty time limits still need to be addressed, the Corporate Airlines, Delta Connection, Pinnacle, and Go! events have clearly shown that other issues contribute to human fatigue in aircraft operations and that a comprehensive approach that includes company policies and crewmember responsibilities is needed to effectively mitigate the hazards posed by fatigue in the aviation environment.

In addition to issuing safety recommendations, the Safety Board has supported industry initiatives led by the Department of Transportation (DOT) to develop practical fatigue management tools for the transportation industry.[7] In the late 1990s, the DOT's Human Factors Coordinating Committee, a group consisting of representatives from the FAA and other transportation modal administrations, sponsored an Operator Fatigue Management (OFM) Program.[8] The program resulted in several products, including a practical guide addressing fatigue management and countermeasure usage,[9] work schedule representation and analysis software to aid managers and schedulers in evaluating and designing work schedules, and procedures for validating the output of fatigue modeling tools. In response to Safety Recommendation A-06-11, the FAA issued Safety Alert for Operators (SAFO) 06004 on April 28, 2006, which directed operators to the fatigue-related information in the DOT OFM program. According to DOT and industry personnel, the Federal Railroad Administration (FRA)

The FAA indicated in correspondence regarding these safety recommendations that, although a notice for proposed rulemaking (NPRM) was issued in 1995 proposing to amend existing regulations to establish one set of duty period limitations, flight time limitations, and rest requirements for flight crewmembers engaged in air transportation, it encountered a number of technical and operational issues as a result of the NPRM. Because the FAA has not revised the regulations, Safety Recommendations A-94-194, A-95-113, and A-06-10 are classified "Open—Unacceptable Response."

[6] See the following reports for other aviation accidents determined to involve fatigue: (a) National Transportation Safety Board, *Collision with Trees on Final Approach, FedEx Flight 1478, Boeing 727, Tallahassee, Florida, July 26, 2002*, Aircraft Accident Report NTSB/AAR-04/02 (Washington, DC: NTSB, 2002); (b) National Transportation Safety Board, *Runway Overrun During Landing, American Airlines Flight 1420, McDonnell Douglas MD-82, Little Rock, Arkansas, June 1, 1999*, Aircraft Accident Report NTSB/AAR-01/02 (Washington, DC: NTSB, 2002); and (c) National Transportation Safety Board, *Controlled Flight into Terrain, Korean Air Flight 801, Boeing 747-300, HL7468, Nimitz Hill, Guam, August 6, 1997*, Aircraft Accident Report NTSB/AAR-00/01 (Washington, DC: NTSB, 2000). (d) National Transportation Safety Board, *Uncontrolled Collision With Terrain, American International Airways Flight 808, Douglas DC-8-61, N814CK, U.S. Naval Air Station, Guantanamo Bay, Cuba, August 18, 1993*, Aircraft Accident Report NTSB/AAR-94/04 (Washington, DC: NTSB, 1994).

[7] NTSB/AAR-04/02 and NTSB/AAR-06/01.

[8] This effort was established as part of the "ONEDOT" program to coordinate resources among DOT agencies. One of the goals of the effort was to reduce the number of accidents and injuries related to operator fatigue.

[9] U.S. Department of Transportation, Research and Special Programs Administration, *Commercial Transportation Operator Fatigue Management Reference* (Washington, DC: RSPA, 2003).

has tested and incorporated in the railroad industry some of the tools resulting from the OFM program.[10] The FAA has not yet applied such tools in the aviation industry.

Fatigue Management Systems

A fatigue management system[11] is a system developed to address the problems associated with fatigue in an operational environment and designed to take a comprehensive, tailored approach to the problem of fatigue within an industry or a workplace. Fatigue management systems commonly incorporate various strategies to manage fatigue (for example, scheduling policies and practices,[12] attendance policies, education, medical screening and treatment, personal responsibility during nonwork periods, task/workload issues, rest environments, commuting policies, and/or napping policies) and an organizational plan for implementing, supervising, and evaluating the system. Once implemented, fatigue management systems are intended to mitigate human fatigue, which would, in turn, reduce the probability of human-error-caused incidents and accidents. Other goals of such systems may include improving the health and well-being of the workforce and increasing productivity.

In 1995, the Civil Aviation Authority (CAA) of New Zealand revised *Civil Aviation Rules* Part 121, Subpart K, "Fatigue of Flight Crew," to allow air carriers to comply with either a standard prescriptive flight and duty time regulation or an alternative CAA-approved fatigue management system. The revised rule states that an operator must establish and gain acceptance of a "scheme" that addresses a long list of factors relating to fatigue, including rest periods before flight, time zones, night operations, multi- and single-pilot operations, mixed duties, "dead-head" transportation, reserve or standby periods, in-flight relief, cumulative duty and flight times, circadian rhythms, and record-keeping.[13] Additionally, the regulations prescribe specific monthly and annual maximum flight hours for flight crewmembers and require operators to keep accurate records of flight and duty times for each crewmember. The regulations also state that fatigued crewmembers must not fly and that operators must not permit fatigued crewmembers to fly if the crewmember's fatigue could endanger the safety of the aircraft or its occupants.

Other countries and international organizations have supported the concept of fatigue management systems in aviation. Australia's Civil Aviation Safety Authority (CASA) has established a working group consisting of industry and CASA subject-matter experts to develop regulatory and advisory material concerning fatigue management systems. Further, in Canada, fatigue management systems are considered part of an overall safety management system, and Transport Canada has made available multiple guidance documents for organizations and

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[10] U.S. Department of Transportation, Federal Railroad Administration, *Validation and Calibration of a Fatigue Assessment Tool for Railroad Work Schedules,* Summary Report DOT-06/21 (Washington, DC: FRA, 2006).

[11] Fatigue management systems can also be referred to as fatigue risk management programs, fatigue management schemes, fatigue countermeasures programs, or alertness management programs. For the purposes of this letter, the term fatigue management systems will be used.

[12] Scheduling policies and practices could include written policies and/or the use of fatigue modeling software tools to assist in roster development.

[13] CAA Advisory Circular 119-2, Revision 2, "Air Operations – Fatigue of Flight Crew," dated October 27, 2006, provides specific guidance to operators on how to demonstrate compliance of their fatigue management schemes.

individuals on its website.[14] Additionally, the International Civil Aviation Organization (ICAO) is drafting a Standards and Recommended Practices document that will discuss fatigue management systems.

Further, the FAA stated in its 2007 and 2008 reports to Congress concerning the regulatory status of the safety recommendations on the Safety Board's Most Wanted List of Transportation Safety Improvements that it is working with ICAO "to develop a Fatigue Risk Management System…to regulate flight and duty time."[15] Although the FAA has not yet published any specific guidance for operators concerning fatigue management systems, several U.S. operators have suggested that they are developing such systems, and at least one operator has voluntarily implemented such a system on a trial basis.[16]

Some of the U.S. operators developing fatigue management systems are doing so in conjunction with their ultra-long-range (ULR) operations (that is, operations with planned flight sector lengths of more than 16 hours). Risks associated with fatigue are a major concern for ULR aviation operations, and industry efforts to gain approval to conduct these operations have driven efforts to develop fatigue management systems. For example, in 2003, an international ULR steering committee published a set of consensus positions that referenced best and recommended practices for validating fatigue management systems.[17] A subsequent report suggested that there was a "trickle down" effect from the ULR effort into long-range and short-range operations.[18] The Safety Board recognizes that efforts could also be made to apply fatigue management systems to the domestic, short-range segment of the aviation industry, represented by operators such as American Connection, Delta Connection, Pinnacle, and Go!. Domestic, short-haul operators do not provide their pilots with advantages such as sleeper berths and relief crews because, for short-range domestic flights, these fatigue mitigators may not be viable; however, other approaches could be integrated into a fatigue management system that addresses this segment of the industry.

Because of the complex nature of the factors that contribute to fatigue, no one solution for fatigue prevention in the aviation industry exists. Therefore, fatigue management systems cannot simply replace flight and duty time limits. Hours-of-service regulations set flight and duty limits that must reflect current scientific evidence and industry experience to provide a valid basis upon which fatigue management systems can operate. For example, accident data show that airline accidents involving human performance errors tend to increase dramatically among pilots

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[14] See <http://www.tc.gc.ca/civilaviation/SMS/FRMS/menu.htm>.

[15] (a) U.S. Department of Transportation Annual Report to Congress and the National Transportation Safety Board on the Regulatory Status of Each Recommendation on the National Transportation Safety Board's Most Wanted List (Washington, DC: DOT, 2007) and (b) U.S. Department of Transportation Annual Report to Congress and the National Transportation Safety Board on the Regulatory Status of Each Recommendation on the National Transportation Safety Board's Most Wanted List (Washington, DC: DOT, 2008).

[16] M.R. Rosekind, K.B. Gregory, and M.M. Mallis, "Alertness Management in Aviation Operations: Enhancing Performance and Sleep," *Aviation, Space, and Environmental Medicine*, Vol. 77, No. 12 (Alexandria, Virginia: 2006): 1256-1266.

[17] Flight Safety Foundation, "Consensus Emerges from International Focus on Crew Alertness in Ultra-Long-Range Operations," *Flight Safety Digest* (Alexandria, Virginia: May/June 2003): 1-21.

[18] Flight Safety Foundation, "Fourth Workshop Yields Insights into Early Ultra-Long-Range Flight Experience," *Flight Safety Digest* (Alexandria, Virginia: August/September 2005): 1-15.

who have been on continuous duty for more than 12 hours.[19] Such evidence should be considered in hours-of-service regulations, which currently permit continuous duty periods of 16 hours without explicit opportunity for restorative rest. Such a modification is unlikely to come about across industry on the basis of individual fatigue management systems. As noted, the Safety Board has repeatedly made recommendations to revise hours-of-service regulations and urges the FAA to take action on these recommendations. However, the Board recognizes that a comprehensive system, which would involve actions by flight crewmembers, operators, and regulators, could be a useful complement to revised flight and duty time regulations to effectively address the complex factors related to fatigue in the aviation environment.

Fatigue Management Systems Guidance and Evaluation

Most groups that have adopted fatigue management systems have included an evaluation component as part of their systems. For example, a recent evaluation of the fatigue management system voluntarily implemented by the U.S. domestic airline industry, which included scheduling changes and education about sleep, sleep disorders, circadian rhythms, and "alertness strategies," showed that the system resulted in increases in daily sleep and improved performance.[20] In addition, a group of scientists associated with the U.S. operators that have developed ULR fatigue management systems is currently developing a standardized evaluation protocol that will be used to evaluate the effectiveness of the systems. Further, one airline in the United Kingdom collected data on its existing schedule system and found significant performance decrements among flight crews over the course of a typical work tour.[21] Based on those findings, the airline applied for, and was granted by its regulatory authority, a temporary variance from the flight and duty regulations under the provision that the operator could demonstrate that the scheduling changes would not lead to an increase in crew fatigue. A subsequent study tracked crew performance and errors and showed a significant improvement under the modified schedule.[22]

Although these results are encouraging, not all fatigue management systems have experienced similar success. Several years after the CAA of New Zealand modified its regulations to accommodate fatigue management schemes, a study was conducted to evaluate how operators were managing fatigue.[23] The study found that the number of fatigue management strategies employed varied considerably by the type of operation and concluded that these strategies were neither better nor worse than prescriptive flight and duty time regulations at

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[19] (a) J.H. Goode, "Are Pilots at Risk of Accidents Due to Fatigue?" *Journal of Safety Research*, Vol. 34 (2005): 309-313 and (b) National Transportation Safety Board, *A Review of Flightcrew-Involved Major Accidents of U.S. Carriers 1978 through 1990*, Safety Study NTSB/SS-94/01 (Washington, DC: NTSB, 1994).

[20] M.R. Rosekind, K.B. Gregory, and M.M. Mallis, 1256-1266.

[21] R. Abboud and S. Stewart, "Flight Crew Scheduling, Performance and Fatigue in a UK Airline – Phase 1," *Proceedings 2005 International Conference on Fatigue Management in Transportation Operations, September 11-15, Seattle, Washington* (Seattle, Washington: 2005).

[22] R. Abboud and S. Stewart, "Flight Crew Scheduling, Performance and Fatigue in a UK Airline – Phase 2," *Proceedings 2005 International Conference on Fatigue Management in Transportation Operations, September 11-15, Seattle, Washington* (Seattle, Washington: 2005).

[23] D. Ratieta, L. Signal, and P. Gander, *Fatigue Management in the New Zealand Aviation Industry*, Australian Transport Safety Bureau, ATSB Research and Analysis Report B2004/0048 (Canberra, Australia: ATSB, 2006).

mitigating fatigue. As shown, work is being done in the area of fatigue management systems, yet these systems are still in their infancy, and the efficacy of some are questionable.

Although some fatigue management systems have shown promise, such as the ULR and the United Kingdom airline systems, these examples are specific to certain operations, and adequate information is not available to determine what systems may be the most successful in alleviating fatigue-related errors and accidents for all operators or situations. Although the FAA has stated that it is working with ICAO to develop a fatigue management system to regulate flight and duty time, it has not provided guidance to operators on what such a system should comprise. Without better guidance, operators may not be aware of the best practices to apply to a fatigue management system or of the scope needed for such a system. The Safety Board recognizes that a comprehensive system, which would involve actions by flight crewmembers, operators, and regulators, could be a useful complement to revised flight and duty time regulations to effectively address the complex factors related to fatigue in the aviation environment.

Therefore, the Safety Board believes that the FAA should develop guidance, based on empirical and scientific evidence, for operators to establish fatigue management systems, including information about the content and implementation of these systems. Such guidance should apply to flight crews and could also be expanded to apply to other aviation workers, such as cabin crews or maintenance personnel.

The Safety Board notes that, in correspondence relating to Safety Recommendation A-06-11, the FAA has stated that, in addition to issuing SAFO 06004, fatigue has always been noted in Advisory Circular (AC) 120-51, "Crew Resource Management Training," as one of the most important factors degrading situational awareness and overall crew performance. However, the continued occurrences of fatigue-related accidents and incidents indicate that the information contained in AC 120-51 and the issuance of SAFO 06004 have not been effective in preventing fatigue-related events. Therefore, Safety Recommendation A-08-44 will supersede Safety Recommendation A-06-11, which is classified "Closed—Acceptable Action/Superseded."

Once fatigue management systems are in place, it is imperative that operators, as well as the FAA, ensure that the systems are performing as intended. The FAA must be involved because of the nature of its oversight and its overarching responsibility to ensure the safety of the aviation industry. Therefore, fatigue management systems must be evaluated to determine whether they effectively mitigate fatigue and to identify key components to make them more effective.

Many challenges exist to evaluating the value of fatigue management systems.[24] For example, it needs to be determined whether a fatigue management system should be expected to improve outcomes and, if so, by how much. In the case of ULR operations, the international steering committee recommended that ULR fatigue management systems should be "sufficiently

[24] A. Williamson and R. Friswell, "Evaluating Fatigue Management Strategies for Long Distance Road Transport," *Proceedings of the 2005 International Conference on Fatigue Management in Transportation Operations, September 11-15, 2005, Seattle, Washington* (Seattle, Washington: 2005).

rigorous to ensure operational safety equivalent to or better than that in current long range operations."[25] Because ULR flights can be more demanding than traditional long-range operations, it may be appropriate to set a standard of no change in safety outcomes. However, the ostensible and logical goal of many fatigue management systems is to reduce fatigue and improve performance and safety. Therefore, the expected indicators of the success of such systems need to be established to properly evaluate such systems. Another challenge with evaluating fatigue management systems is that fatigue is not an objective measure. It can be very subjective, and it is not always apparent when fatigue is present and whether it contributes directly or indirectly to an error or performance.

A variety of outcomes, including sleep quantity, sleep quality, knowledge of individual fatigue management strategies, and performance, have been used to assess existing scheduling systems or to evaluate the impact of fatigue management systems.[26] Sleep quantity is typically measured using objective wrist activity monitors that track an individual's physical activity and movement or subjective sleep diaries. Sleep quality and knowledge of fatigue management strategies are typically assessed using interviews or surveys. In terms of performance, some studies have employed computerized performance assessments such as the Psychomotor Vigilance Task,[27] which has been demonstrated to be sensitive to sleep loss. Other studies have tracked actual performance in operational settings using flight data monitoring programs or line operation safety audits. Other measures that have been proposed include tracking absenteeism rates and incident and accident rates.[28]

Fatigue management systems appear to hold promise as a progressive approach to addressing the problems associated with fatigue in aviation environments, especially because physiological, behavioral, self-report, and operational evidence are used to provide a scientific basis for establishing and evaluating such systems. As noted, such systems are needed as a complement to, not a replacement for, revised flight and duty time regulations, which were recommended in Safety Recommendations I-89-3, A-99-45, and A-06-10 and still have not been revised. However, the experience of the New Zealand airlines suggest that, although many individual systems appear promising in principle, refinement and ongoing oversight are necessary to ensure that they are resulting in the intended outcomes.

Therefore, the Safety Board believes that the FAA should develop and use a methodology that will continually assess the effectiveness of fatigue management systems implemented by operators, including their ability to improve sleep and alertness, mitigate performance errors, and prevent incidents and accidents.

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[25] Flight Safety Foundation (May/June, 2003): 12.

[26] See, for example, (a) M.R. Rosekind, K.B. Gregory, and M.M. Mallis, 1256-1266; R. Abboud and S. Stewart (2005) and (b) G.D. Roach, M.J.W. Thomas, and R.M. Petreilli, "The Impacts of Australian Transcontinental 'Back of Clock' Operations on Sleep and Performance in Commercial Aviation Flight Crew," Australian Transport Safety Bureau Transport Safety Report (Canberra, Australia: ATSB, March 2007).

[27] The Psychomotor Vigilance Task, which can be administered using a hand-held computer, is a sustained attention task that involves responding as quickly as possible to a visual stimulus.

[28] J. Booth-Bourdeau, I. Marcil, M. Laurence, K. McCulloch, and D. Dawson, "Development of Fatigue Risk Management Systems for the Canadian Aviation Industry," *Proceedings 2005 International Conference on Fatigue Management in Transportation Operations, September 11-15, Seattle, Washington* (Seattle, Washington: 2005).

Therefore, the National Transportation Safety Board makes the following recommendations to the Federal Aviation Administration:

> Develop guidance, based on empirical and scientific evidence, for operators to establish fatigue management systems, including information about the content and implementation of these systems. (A-08-44) (This safety recommendation supersedes Safety Recommendation A-06-11.)
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> Develop and use a methodology that will continually assess the effectiveness of fatigue management systems implemented by operators, including their ability to improve sleep and alertness, mitigate performance errors, and prevent incidents and accidents. (A-08-45)

In response to the recommendations in this letter, please refer to Safety Recommendations A-08-44 and -45. If you would like to submit your response electronically rather than in hard copy, you may send it to the following e-mail address: correspondence@ntsb.gov. If your response includes attachments that exceed 5 megabytes, please e-mail us asking for instructions on how to use our Tumbleweed secure mailbox procedures. To avoid confusion, please use only one method of submission (that is, do not submit both an electronic copy and a hard copy of the same response letter).

Chairman ROSENKER, Vice Chairman SUMWALT, and Members HERSMAN, HIGGINS, and CHEALANDER concurred with these recommendations.

[*Original Signed*]

By: Mark V. Rosenker
Chairman