Safety Report

Evaluation of U.S. Department of Transportation Efforts in the 1990s to Address Operator Fatigue

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National Transportation Safety Board
490 L'Enfant Plaza, S.W.
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Contents

Acronyms Used in the Report

AAA	American Automobile Association
ANPRM	advance notice of proposed rulemaking
ARAC	Aviation Rulemaking Advisory Committee
ASRS	Aviation Safety Reporting System
CFR	*Code of Federal Regulations*
DOT	U.S. Department of Transportation
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
GT	gross ton
NASA	National Aeronautics and Space Administration
NHTSA	National Highway Traffic Safety Administration
NPRM	notice of proposed rulemaking
RSPA	Research and Special Programs Administration
U.S.C.	*United States Code*
USCG	United States Coast Guard

Executive Summary

During the 1980s, the National Transportation Safety Board investigated several aviation, highway, and marine accidents that involved operator fatigue. Following completion of these accident investigations, the Safety Board in 1989 issued three recommendations to the U.S. Department of Transportation (DOT) addressing needed research, education, and revisions to hours-of-service regulations.

Ten years have passed since these safety recommendations were issued. In the interim, the Safety Board has issued more than 70 additional recommendations to the DOT, States, industry, and industry associations to reduce the incidence of fatigue-related accidents. In response to the three 1989 recommendations, the DOT and the modal administrations have, in general, acted and responded positively to the recommendations addressing research and education; little action, however, has occurred with respect to revising the hours-of-service regulations. Nevertheless, the Safety Board believes that support has grown in recent years to make substantive changes to these regulations.

This report provides an update on the activities and efforts by the DOT and the modal administrations to address operator fatigue and, consequently, the progress that has been made in the past 10 years to implement the actions called for in the three intermodal recommendations and other fatigue-related recommendations. The report also provides some background information on current hours-of-service regulations, fatigue, and the effects of fatigue on transportation safety.

As a result of this safety report, the National Transportation Safety Board issued new safety recommendations to the U.S. Department of Transportation, the Federal Aviation Administration, the Federal Highway Administration, the Federal Railroad Administration, the Research and Special Programs Administration, and the United States Coast Guard. The Safety Board also reiterated two recommendations to the Federal Aviation Administration.

Part 3

DOT Response to the Safety Board's Intermodal Recommendations

The various Secretaries of the DOT and modal Administrators over the years have expressed their concerns about operator fatigue. In a 1995 summary of the DOT's fatigue safety effort, Federico Peña, then Secretary of the DOT, stated that "fatigue among transportation operators remains a critical safety problem."[30] In a 1999 update, Secretary Rodney Slater stated, "We know that alertness is a key to safe vehicle operation. To reduce crashes and accidents and their personal and financial consequences, we need to ensure that vehicle operators are ready and capable of operating their vehicles or other transportation equipment."[31] Despite the many statements made by the DOT about the importance of addressing fatigue in transportation, only one of the three intermodal recommendations issued to the DOT more than 10 years ago has been fully implemented (I-89-1).

Safety Recommendation I-89-1

Safety Recommendation I-89-1 asked the DOT to expedite a coordinated research program on the effects of fatigue, sleepiness, sleep disorders, and circadian factors on transportation system safety. In its August 1989 response, the DOT stated that coordinated research efforts on human factors—including the effects of fatigue, sleepiness, sleep disorders, and circadian factors—on transportation safety was a top priority. The Human Factors Coordinating Committee, formed in 1988 and comprising representatives from each of the DOT administrations, serves as a means to share research information. A subcommittee has been created to focus on fatigue-related issues. In addition, the DOT briefed the Safety Board about the various ongoing fatigue-related projects several times over the years. Safety Recommendation I-89-1 was classified "Closed—Acceptable Action" on July 19, 1996, because the DOT had made Department-wide research efforts on operator fatigue. At the time this recommendation was closed, the FAA, FHWA, NHTSA, FRA, and USCG all had fatigue-related research projects underway.[32] In the Safety Board's 1996 letter closing the recommendation, the Board encouraged the DOT to continue its research efforts, which it generally has done.

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[30] U.S. Department of Transportation. November 1995. *Sharing the Knowledge: Department of Transportation Focus on Fatigue*. Washington, DC.

[31] U.S. Department of Transportation. March 1999. *Managing Fatigue: A Significant Problem Affecting Safety, Security, and Productivity*. Washington, DC.

[32] U.S. Department of Transportation. November 1995. *Sharing the Knowledge: Department of Transportation Focus on Fatigue*. Washington, DC.

From fiscal years 1990 through 1998, the DOT spent more than $30 million on fatigue research. A wide range of research projects has been initiated, such as developing in-vehicle alerting systems, using high fidelity simulators to determine how different work schedules affect fatigue and performance, studying the effects of loading and unloading, and evaluating technologies that monitor operator performance to indicate fatigue. Table 3–1 identifies major research projects completed by the DOT since 1989.[33]

The Safety Board is disappointed that more research efforts have not been made by the Research and Special Programs Administration (RSPA) in the pipeline mode. In 1998, the Board asked RSPA to assess the potential safety risks associated with rotating pipeline controller shifts and to establish industry guidelines for the development and implementation of pipeline controller work schedules that reduce the likelihood of accidents attributable to controller fatigue (Safety Recommendation P-98-30).[34] The RSPA responded to the recommendation on May 4, 1999.

The Safety Board is aware that industry groups such as the Association of American Railroads and the American Trucking Associations, Inc., have also participated in and conducted research on operator fatigue since the 1989 intermodal recommendations were issued. Additionally, the transportation industry participates in meetings and shares its research findings with other organizations. The FRA has formed the North American Rail Alertness Partnership comprising railroad management, union leadership, and FRA representatives that discuss fatigue and exchange information on countermeasures to reduce fatigue. The FHWA and NHTSA are participants in the National Drowsy Driving Coordinating Committee sponsored by the National Sleep Foundation. This is a forum for sharing research and educational outreach efforts among government, State, industry, and nonprofit groups in the highway mode.

The DOT's efforts to coordinate operator fatigue research have generally been responsive, with the exception of the RSPA regarding pipeline operations. The Safety Board encourages the DOT to continue its research, particularly on technology and in the pipeline mode, and to share information across the modes and with industry.

[33] The Safety Board notes that many of the research projects listed in the DOT's 1999 update were also listed in the DOT's 1995 publication on transportation fatigue.

[34] National Transportation Safety Board. 1998. *Pipeline Rupture and Release of Fuel Oil Into the Reedy River at Fork Shoals, South Carolina, June 26, 1996*. Pipeline Accident Report NTSB/PAR-98/01. Washington, DC.

Table 3–1. Fatigue-related research completed in the U.S. Department of Transportation since 1989.

Federal Aviation Administration:

Effect of Alcohol and Fatigue on an FAA Readiness-To-Perform Test. (DOT/FAA/AM-95/24)

Handbook of Human Performance Measures and Crew Requirements for Flightdeck Research. (DOT/FAA/CT-TN95/49)

Some Effects of 8- vs. 10-Hour Work Schedules on the Test Performance/Alertness of Air Traffic Control Specialists. (DOT/FAA/AM-95/32)

Shift Work, Age, and Performance—Investigation of the 2-2-1 Shift Schedule Used in Air Traffic Control Facilities: 1. The Sleep/Wake Cycle. (DOT/FAA/AM-95/19)

Human Factors in Aviation Maintenance: Phase 3, Volume 1, Progress Report. (DOT/FAA/AM-95/13)

Handbook of Human Performance Measures and Crew Requirements for Flightdeck Research. (DOT/FAA/CT-TN95/49)

Federal Highway Adminstration:

In-Cab Fitness-For-Duty. (FHWA-MC-95-011)

Shipper Involvement in Hours-Of-Service Violations. (FHWA-MC-98-049)

Impact of Local/Short Haul Operations on Driver Fatigue. (DTFH61-C-00105)

Short Haul Trucks and Driver Fatigue. (DTFH61-96-C-00038)

Commercial Motor Vehicle Rest Areas: Making Space for Safety. (PB 97-124705)

Driver Fatigue and Alertness Study. (PB 98-102346)

Local/Short Haul Driver Fatigue Crash Data Analysis. (FHWA-MC-98-016)

Effects of Operating Practices on Driver Alertness. (FHWA-MCRT-99-008)

PERCLOS: A Valid Psychophysiological Measure of Alertness as Assessed by Psychomotor Vigilance. (FHWA-MCRT-98-006)

Electronic On-Board Recorders for Hours-of-Service Compliance. (FHWA-MCRT-99-007)

Conference on Managing Fatigue in Transportation. (cosponsored with NHTSA and the FRA)

Conference on Driver Vigilance Monitoring. (cosponsored with NHTSA)

Federal Railroad Administration:

The Effects of Work Scheduling on Train Handling Performance and Sleep of Locomotive Engineers: A Simulator Study. (DOT/FRA/ORD-97-09)

Enginemen Stress and Fatigue. (Issued February 1993)

Issues in Locomotive Crew Management and Scheduling. (DOT/FRA/RRR-91-01)

National Highway Traffic Safety Administration:

Crashes and Fatalities Related to Driver Drowsiness/Fatigue. (Research Note, issued November 1994)

Validation of Eye and Other Psychophysiological Monitors. (cosponsored with FHWA) (DOT-HS-808 762)

Research on Vehicle-Based Driver Status/Performance Monitoring: Development, Validation, and Refinement of Algorithms for Detection of Driver Drowsiness. (DOT-HS-808 247)

Research on Vehicle-Based Driver Status/Performance Monitoring: Seventh Semiannual Research Report. (DOT-HS-808 299)

Research on Vehicle-Based Driver Status/Performance Monitoring, Part 1. (DOT-HS-808 838)

Research on Vehicle-Based Driver Status/Performance Monitoring, Part 2. (DOT-HS-808 839)

Research on Vehicle-Based Driver Status/Performance Monitoring, Part 3. (DOT-HS-808 840)

Drowsy Driving and Automoble Crashes. (DOT-HS-808 707)

Table 3–1. Fatigue-related research completed in the U.S. Department of Transportation since 1989 (continued).

United States Coast Guard:
Fatigue and alertness in Merchant Marine Personnel: A Field Study of Work and Sleep Patterns. (USCG-D-06-97)
Procedures for Investigating and Reporting Human Factors and Fatigue Contributions to Marine Casualties. (USCG-D-09-97)
Modeling Techniques for Shipboad Manning: A Review and Plan for Development. (USCG-D-07-93)
Maritime Administration:
Shipboard Crew Fatigue, Safety, and Reduced Manning. (issued November 1994)

Sources: (a) U.S. Department of Transportation, Federal Highway Administration, Office of Motor Carriers. December 16, 1998. *Summary of Driver Fatigue Programs.* Washington, DC. (b) Publications on driver fatigue programs listed on the National Technical Information Service World Wide Web home page, <http://www.ntis.gov>, April 22, 1999.

Safety Recommendation I-89-2

Safety Recommendation I-89-2 asked the DOT to develop and disseminate educational material for transportation industry personnel and management regarding shift work; work and rest schedules; and proper regimens of health, diet, and rest. In its 1989 response, the DOT acknowledged the unique demands placed on transportation workers such as shift-work, long-haul operations, and nighttime duty and that it would review its current policy on developing educational materials. In a more detailed response in 1996, the DOT indicated that it had published its 1995 report *Sharing the Knowledge: Department of Transportation Focus on Fatigue* and produced two videotapes that addressed fatigue: one on human factors and one entitled *Fatigue Busters—How to Survive Fatigue in the '90s*. In addition, the FAA also published a fatigue buster brochure. The Safety Board replied that it was pleased that information had been produced for aviation and highway, but it was concerned that similar information had not been developed for railroad, marine, and mass transit. On May 4, 1999, the DOT provided the Safety Board with an update of FRA education activities. Safety Recommendation I-89-2 is currently classified "Open—Acceptable Response."

Other organizations, agencies, and industry groups—such as the National Sleep Foundation, the AAA Foundation for Traffic Safety, and the American Trucking Associations, Inc.—have also developed educational brochures about fatigue. Two brochures, *Awake at the Wheel* and *Wake Up!*, attempt to educate operators about the need for sleep and to dispel myths such as people can always tell when they are fatigued.[35] Appendix E

[35] The brochure *Wake Up!* was developed jointly by the AAA Foundation for Traffic Safety and the National Sleep Foundation. It was the basis for the brochure *Awake at the Wheel* that was developed for truckdrivers by the FHWA in conjunction with the American Trucking Associations.

contains a list of some educational materials that have been developed since the intermodal recommendations were issued.

In the early 1990s, NASA developed an education and training module entitled "Alertness Management in Flight Operations." It contains information about fatigue with an emphasis on aviation. The module has three primary objectives: to explain (1) the current state of knowledge about the physiological mechanisms that underlie fatigue; (2) misconceptions about fatigue; and (3) fatigue countermeasures. The NASA and the FAA have cosponsored many courses to educate pilots for a large segment of the major U.S. air carriers as well as for corporate management. The FRA, Federal Transit Administration (FTA), and FHWA along with industry organizations have used the NASA countermeasures training module as the basis for training modules in the other modes of transportation.

In addition to Safety Recommendation I-89-2, the Safety Board has issued other recommendations to the individual modal administrations calling for increased educational efforts regarding the effects of fatigue. In 1995, the Safety Board asked the FHWA to develop and disseminate, in consultation with DOT's Human Factors Coordinating Committee, a training and education module to inform truckdrivers of the hazards of driving while fatigued (Safety Recommendation H-95-5).[36] The FHWA and the American Trucking Associations, Inc., adapted the NASA module for use with the commercial driving industry and developed a train-the-trainer course on fatigue and fatigue countermeasures. To date more than 2,000 people have been trained; 16 seminars are being offered in 1999. Safety Recommendation H-95-5 to the FHWA was classified "Closed—Acceptable Action" on July 7, 1998.

In 1996, the Safety Board also asked the FTA, in cooperation with the American Public Transit Association, to develop a fatigue educational awareness program and to distribute it to transit agencies to use in their fitness-for-duty training for supervisors and employees involved in safety-sensitive positions (Safety Recommendation R-96-20).[37] The FTA has developed a seminar, available in four different formats, for a variety of attendees including employees, managers, and persons involved in scheduling. The Safety Board is pleased with this effort of the FTA and is aware that more than 600 persons have attended the seminars. As a result of these efforts, the Safety Board has classified Safety Recommendation R-96-20 "Closed—Acceptable Action."

In aviation, the Safety Board asked the FAA to require U.S. air carriers operating under 14 CFR Part 121 to provide educational programs for pilots (Safety Recommendation A-94-5),[38] to require 14 CFR Part 135 air carriers to provide fatigue countermeasure

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[36] National Transportation Safety Board. 1995. *Factors That Affect Fatigue in Heavy Truck Accidents*. Safety Study NTSB/SS-95/01 and NTSB/SS-95/02. Washington, DC.

[37] National Transportation Safety Board. *Collision Involving Two New York City Subway Trains on the Williamsburg Bridge in Brooklyn, New York, June 5, 1995*. Railroad Accident Report NTSB/RAR-96/03. Washington, DC.

[38] National Transportation Safety Board. 1994. *A Review of Flightcrew-Involved, Major Accidents of U.S. Air Carriers, 1978 Through 1990*. Safety Study NTSB/SS-94/01. Washington, DC.

information to air crews in initial and recurrent training (A-94-73),[39] and to provide fatigue information to the general aviation community (A-97-20).[40] The FAA revised Advisory Circular 120-51B to include fatigue as one of the topics discussed in crew resource management training. The FAA also developed educational materials to address the hazards of fatigue for use in safety meetings. These three recommendations have been classified "Closed—Acceptable Action."[41]

In 1997, the Safety Board asked the USCG to advise marine pilots about the effects of fatigue on performance and about sleeping disorders such as sleep apnea (Safety Recommendation M-97-41).[42] In a letter dated November 11, 1998, the USCG indicated that it has discussed the effects of fatigue and sleeping disorders with the American Pilots Association and independent pilot associations, requesting that they inform their members of the dangers of sleeping disorders such as sleep apnea through their internal media. Further, Navigation and Vessel Inspection Circular No. 2-98, *Physical Evaluation Guidelines for Merchant Marine's Documents and Licenses*, contains guidelines for use by physicians performing physical examinations of mariners and includes sleeping disorders as conditions to be evaluated for original and renewals of marine pilots' licenses and for the required pilots' physicals. Safety Recommendation M-97-41 was classified "Closed—Acceptable Action" on April 6, 1999.

The Safety Board is aware that the USCG has developed a research and educational program on crew endurance. The Board is also aware that the USCG held a workshop on fatigue on April 6, 1999, aimed at masters and safety management personnel of tugs and barges, passenger vessels, and fishing vessels as well as USCG personnel. The Board encourages the USCG to add more workshops to its agenda. Such programs could be promoted through the USCG's Prevention Through People program. The USCG has not developed any brochures on operator fatigue for the mariner community.

The Safety Board also issued a recommendation to the FHWA asking that educational materials be developed for commercial truckdrivers (H-90-21, classified "Closed—Acceptable Action"). As shown in appendix E, the FHWA has developed and disseminated the brochure *Awake at the Wheel* and fatigue videos; it has also developed courses to educate truckdrivers about the dangers of driving while drowsy. In February 1999, the Board asked the FHWA to ensure that the dangers of inverted sleep periods are discussed in the fatigue video being developed for motorcoaches (Safety Recommendation H-99-4A).

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[39] National Transportation Safety Board. 1994. *In-Flight Loss of Control, Leading to Forced Landing and Runway Overrun, Continental Express, Inc., N24706, Embraer EMB-120 RT, Pine Bluff, Arkansas, April 29, 1993*. Aircraft Accident Report NTSB/AAR-94/02/SUM. Washington, DC.

[40] National Transportation Safety Board. 1997. *In-Flight Loss of Control and Subsequent Collision With Terrain, Cessna 177B, N35207, Cheyenne, Wyoming, April 11, 1996.* Aircraft Accident Report. NTSB/AAR-97/02. Washington, DC.

[41] Safety Recommendations A-94-5 and A-94-73 were classified "Closed—Acceptable Action" on January 16, 1996; Safety Recommendation A-97-20 was classified "Closed—Acceptable Action" on June 11, 1997.

[42] National Transportation Safety Board. 1997. *Grounding of Liberian Passenger Ship* Star Princess *on Poundstone Rock, Lynn Canal, Alaska, June 13, 1995.* Marine Accident Report NTSB/MAR-97/02. Washington, DC.

The Safety Board is pleased to see the increase in educational efforts on fatigue among the DOT modal administrations, particularly the current activities within the FTA. The Safety Board would like to see more efforts in marine and pipeline to develop and disseminate educational materials on fatigue and will continue to monitor these activities. The FAA, FHWA, FRA, and FTA have satisfactorily met the intent of this recommendation; however, the Board urges these modal administrations to continue their efforts in this area. Pending further efforts by the RSPA and the Coast Guard to develop and disseminate educational information on fatigue in marine and pipeline operations, respectively, Safety Recommendation I-89-2 remains classified "Open—Acceptable Response."

Safety Recommendation I-89-3

Safety Recommendation I-89-3 asked the DOT to review and upgrade regulations governing hours of service to assure that they are consistent and that they incorporate the results of the latest research on fatigue and sleep issues. In 1989, the DOT stated that it was reviewing the regulations pertaining to hours of service. It had not found research to suggest that the regulations should be consistent across all modes of transportation and that it would continue with research efforts to determine what changes might be made.

The Board has been very disappointed in the DOT's lack of progress in revising the hours-of-service regulations. Subsequently, the Safety Board made specific recommendations to the FAA and FHWA to revise the hours-of-service regulations. In conjunction with its investigation of the crash of American International Airways at Guantanamo Bay, Cuba, in August 1993,[43] the Safety Board recommended that the FAA

> Revise the applicable subpart of 14 CFR Part 121 to require that flight time, accumulated in noncommercial "tail end" ferry flights conducted under 14 CFR Part 91 as a result of 14 CFR Part 121 revenue flights, be included in the flight crewmember's total flight and duty time accrued during those revenue operations. (A-94-105, classified "Closed—Acceptable Action/Superseded" by Safety Recommendation A-95-113)
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> 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. (A-94-106, classified "Closed—Acceptable Action/Superseded" by Safety Recommendation A-95-113)

[43] National Transportation Safety Board. 1994. *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.

In its report of the accident involving an Air Transport International DC8-63 at Kansas City International Airport in February 1995,[44] the Safety Board recommended that the FAA

> 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 take into consideration research findings on fatigue and sleep issues. 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 limitation of 14 CFR Part 121 or other appropriate regulations. (A-95-113, currently classified "Open—Acceptable Response")

In its study of aviation safety in Alaska,[45] the Safety Board asked the FAA to

> Develop appropriate limitations on consecutive days on duty, and duty hours per duty period for flight crews engaged in scheduled and nonscheduled commercial flight operations, and apply consistent limitations in Alaska and the remainder of the United States. (A-95-125, currently classified "Open—Acceptable Response")

On June 15, 1992, the FAA announced the establishment of the flight crewmember flight/duty rest requirements working group of its Aviation Rulemaking Advisory Committee (ARAC). In its final report submitted to the FAA on June 30, 1994, the working group indicated that although it had not reached consensus on the specific issues, it did agree on four major areas that should be addressed in FAA rulemaking: absence of a duty time limitation, reserve scheduling, back-side-of-the-clock operations, and scheduled reduced rest.

The FAA issued a notice of proposed rulemaking (NPRM) on December 20, 1995,[46] 6 years after the Board issued Safety Recommendation I-89-3. The proposed flight time and rest requirements are provided in appendix F. Comments on the NPRM were originally due on March 19, 1996; however, the comment period was extended to June 19, 1996. The Board commented on the rulemaking on June 19, 1996, noting several favorable aspects to the NPRM:

- elimination of the ability of carriers to schedule flight crewmember duty during scheduled rest periods, inclusion of standby reserve time, deadheading time, and all duties performed for the airline as duty time in the determination of flight and duty time requirements;

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[44] National Transportation Safety Board. 1995. *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-95/05. Washington, DC.

[45] National Transportation Safety Board. 1995. *Aviation Safety in Alaska.* Safety Study NTSB/SS-95/03. Washington, DC.

[46] *Federal Register*, Vol. 60, No. 244, dated December 20, 1995.

- inclusion of ferry, instructional, maintenance, check, and other flights in the determination of flight and duty time requirements, requirements of minimum daily rest periods of at least 10 consecutive hours, and 36 consecutive hours of rest within 7 consecutive calendar days of duty, for flight crewmembers and flight engineers;
- establishment of explicit standards for approving on-board flight crew rest areas;
- permit extensions of daily flight and duty intervals to periods of no more than 2 hours and only for operational reasons beyond the control of the airline; and
- limits of duty periods for crewmembers on reserve assignments depending on the amount of advance notification of reporting time.

In its comments on the rulemaking, however, the Board also expressed concern that the proposed rule did not include effective mechanisms to address flight operation during the circadian night and circadian trough, and it lacked recognition of the fatiguing aspects of multiple takeoffs and landings. There were mixed industry reactions to the NPRM. In general, air carriers and air carrier organizations opposed the NPRM[47] whereas pilot associations supported the proposal with some reservations, primarily a concern with loss of income from reduced flying hours and a desire for a more thorough discussion of back-side-of-the-clock flying time. According to the FAA, it received about 2,000 comments on the NPRM.

With no action since 1996 and the rulemaking effectively abandoned, on July 9, 1998, the ARAC on air carrier operations was assigned to provide a review and analysis of industry practice with regard to reserve duty for flight crewmembers, which is only a small part of the flight and duty time issue. A working group was formed and ultimately delivered recommendations to the FAA on February 9, 1999.[48] The pilots and air carriers on the working group were able to agree on the following:

1. A pilot should be scheduled by the operator to receive a protected time period as an opportunity to sleep for every day of reserve duty. The operator may not contact the pilot during this period.
2. An operator should limit the movement of the pilot's protected time period during consecutive days of reserve duty to ensure circadian stability.
3. A reserve pilot's availability for duty should be limited to prevent pilot fatigue as a result of lengthy periods of time-since-awake.
4. Sufficient advance notice of a flight assignment can provide a reserve pilot with a sleep opportunity.

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[47] Batelle Memorial Institute. March 1998. *A Review of Issues Concerning Duty Period Limitations, Flight Time Limitations, and Rest Requirements as Stated in the FAA's Notice of Proposed Rulemaking 95-18*. Washington, DC: Federal Aviation Administration.

[48] Aviation Rulemaking Advisory Committee, Reserve Rest Working Group. January 8, 1999. *Pilot Members Submission: Proposal of 77,955 Airline Pilots*.

The pilots and the air carriers, however, could not reach agreement about how to meet these goals. The Safety Board understands the difficulty in reaching an agreement on the issue of reserve duty and rest; nevertheless, it remains deeply concerned and disappointed that no further rulemaking action has been taken on the overall issue of hours of service and that duty and rest requirements continue to be different for Part 121 and Part 135 operations. According to the FAA, rather than proceed to a final rule with the NPRM, it will likely issue a supplemental NPRM, which, in the Safety Board's opinion, will only further delay any resolution to this important safety issue.

In its 1995 study on factors that affect fatigue in heavy truck accidents,[49] the Safety Board asked the FHWA to

> Complete rulemaking within 2 years to revise 49 CFR 395.1 to require sufficient rest provisions to enable drivers to obtain at least 8 continuous hours of sleep after driving for 10 hours or being on duty for 15 hours. (H-95-1, currently classified "Open—Unacceptable Response")
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> Complete rulemaking within 2 years to eliminate 49 CFR 395.1 paragraph (h), which allows drivers with sleeper berth equipment to cumulate the 8 hours of off-duty time in two separate periods. (H-95-2, currently classified "Open—Unacceptable Response")

In November of 1996, the FHWA issued an advance notice of proposed rulemaking (ANPRM) that requested additional fatigue research.[50] Rather than proposing any changes to the current hours-of-service regulations, the ANPRM was a general solicitation for comments on hours-of-service regulations. The comment period closed on March 31, 1997. The FHWA received about 1,600 comments to the ANPRM. An expert panel was convened in the summer of 1998 to review and evaluate, based on selected scientific criteria established by the panel, a series of hours-of-service proposals. None of the proposals met the scientific criteria established. The expert panel also developed an additional proposal intended to meet the scientific criteria established. A summary of these proposed hours-of-service regulations is provided in appendix G.

Currently, the FHWA has reported that it is pursuing two different avenues of rulemaking—traditional rulemaking and negotiated rulemaking.[51] In a letter dated November 3, 1998, the FHWA indicated that it intended to publish an NPRM in early 1999, was contracting with the University of Michigan Transportation Research Institute to perform a cost/benefit analysis, and was considering negotiated rulemaking to expedite the process. In a response dated February 25, 1999, to the FHWA, the Safety Board expressed disappointment that it had taken more than 18 months since the ANPRM comment period

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[49] National Transportation Safety Board. 1995. *Factors That Affect Fatigue in Heavy Truck Accidents.* Safety Study NTSB/SS-95/01 and NTSB/SS-95/02. Washington, DC.

[50] *Federal Register*, Vol. 61, No. 215, dated November 5, 1996.

[51] Basically, a procedure by which representatives of all interests affected by a rulemaking are brought together to discuss fully the issues under conditions conducive to narrowing or eliminating differences and to negotiating a proposed rule acceptable to each interest.

closed to reach the NPRM stage and that the FHWA expected that a 120-day comment period on the NPRM would not be sufficiently long to receive comments, thus prolonging activity to issue a final rule. The Safety Board also indicated that it would support a negotiated rule if it would expedite the process. In testimony at the Safety Board's April 14, 1999, public hearing on truck and bus safety,[52] an FHWA representative indicated that a decision on negotiated rulemaking was expected to be made within 2 weeks. The FHWA representative also indicated that development of an NPRM through the traditional process was taking place simultaneously with the discussions on a negotiated rule to avoid any further loss of time.

In a May 4, 1999, letter to the Safety Board, the DOT indicated that "FRA submitted legislation to Congress last year, and may again this year, to require railroads to submit fatigue management plans designed to reduce fatigue experienced by railroad employees." The letter further stated that "should we be successful in gathering support and passage of such a legislative initiative, we believe fatigue will be greatly reduced in railroad operations."

Although the DOT and the modal administrations have taken positive steps in the area of education and research, they have not acted decisively to revise the antiquated hours-of-service regulations. In fact, as outlined above, little regulatory action has been initiated. The DOT believes that countermeasures to fatigue are preferred over regulation because sleep during a rest period cannot be enforced.[53] The Safety Board points out that hours-of-service rules exist to set limits on allowable scheduling practices, not to prescribe those schedules, and while the Board agrees that sleep cannot be regulated, it also believes that time for adequate sleep must be guaranteed by any Federal regulation related to hours of service.

The Safety Board is aware that the FHWA, and others, are looking at onboard devices to test fitness-for-duty and monitor impairment of operator performance. Although the Safety Board supports pre-duty testing for performance as a result of fatigue, alcohol, drugs, or other condition, it does not believe that operators should be driving up to the point that they fail a valid fitness-for-duty test as a result of fatigue, which could occur in the middle of a trip.

In 1998, DOT Secretary Slater launched the ONEDOT program. This program is to build on collaborative efforts among the various transportation agencies to reduce duplication and save resources. One of the goals of ONEDOT is to develop a common, positive framework relating to work hours, overtime, and incentives. Within the concept of ONEDOT, the DOT Safety Council works toward development of a safety policy for the Department. Fatigue is one of the areas on which the Council intends to act.

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[52] The hearing was held April 14–16, 1999, in Washington, D.C. Discussion panels included representatives from the DOT, highway transportation industry, and public safety groups.

[53] U.S. Department of Transportation. 1999. *Managing Fatigue: A Significant Problem Affecting Safety, Security, and Productivity.* Washington, DC.

The Safety Board acknowledges this as yet another initiative to address fatigue and revisions to hours-of-service regulations; nevertheless, the Board remains extremely disappointed in the lack of rulemaking by the DOT.

Scientific research has shown that certain sleep factors can affect fatigue and performance: insufficient sleep, irregular and unpredictable schedules, working during low points in the circadian rhythm. The current hours-of-service regulations do not accommodate these concerns. The Safety Board believes these factors should be considered when revising the hours-of-service regulations. Therefore, the Safety Board recommends that the DOT require the modal administrations to modify the appropriate *Codes of Federal Regulations* to establish scientifically based hours-of-service regulations that set limits on hours of service, provide predictable work and rest schedules, and consider circadian rhythms and human sleep and rest requirements. The Safety Board also recommends that the DOT seek Congressional authority, if necessary, for the modal administrations to establish these regulations. Based on the issuance of this new recommendation, Safety Recommendation I-89-3 is being classified "Closed—Unacceptable Action/Superseded." The Safety Board is also recommending separately that each modal administration—the FAA, FHWA, FRA, USCG, and RSPA—establish, within 2 years, scientifically based hours-of-service regulations that set limits on hours of service, provide predictable work and rest schedules, and consider circadian rhythms and human sleep and rest requirements. Further, because the FAA's efforts have not resulted in any changes to the flight and duty time regulations, the Safety Board has reclassified Safety Recommendations A-95-113 and A-95-125 "Open—Unacceptable Response." These recommendations are being reiterated in conjunction with this report. For the FHWA, the revised regulations, at a minimum and as recommended by the Safety Board in 1995, should also (a) require sufficient rest provisions to enable drivers to obtain at least 8 continuous hours of sleep after driving for 10 hours or being on duty for 15 hours, and (b) eliminate 49 CFR 395.1 paragraph (h), which allows drivers with sleeper berth equipment to cumulate the 8 hours of off-duty time in two separate periods. As a result of this new recommendation to the FHWA, Safety Recommendations H-95-1 and -2 are being classified "Closed—Unacceptable Action/Superseded."

Findings

1. Since 1989, the U.S. Department of Transportation has initiated a wide range of research projects to address the issue of operator fatigue in the transportation environment, with the exception of pipeline operations.

2. Since 1989, the Federal Aviation Administration, the Federal Highway Administration, the Federal Railroad Administration, and the Federal Transit Administration have developed and disseminated various educational materials, including brochures and videotapes, to the industry on the detrimental effects of fatigue in the transportation environment. The Research and Special Programs Administration and the U.S. Coast Guard need to make a more concerted effort to develop and disseminate educational information on fatigue in pipeline and marine operations, respectively.

3. Despite the acknowledgment by the U.S. Department of Transportation that fatigue is a significant factor in transportation accidents, little progress has been made to revise the hours-of-service regulations to incorporate the results of the latest research on fatigue and sleep issues.

Recommendations

As a result of this safety report, the National Transportation Safety Board made the following safety recommendations:

To the U.S. Department of Transportation:

Require the modal administrations to modify the appropriate *Codes of Federal Regulations* to establish scientifically based hours-of-service regulations that set limits on hours of service, provide predictable work and rest schedules, and consider circadian rhythms and human sleep and rest requirements. Seek Congressional authority, if necessary, for the modal administrations to establish these regulations. (I-99-1) (Supersedes I-89-3)

To the Federal Aviation Administration:

Establish within 2 years scientifically based hours-of-service regulations that set limits on hours of service, provide predictable work and rest schedules, and consider circadian rhythms and human sleep and rest requirements. (A-99-45)

To the Federal Highway Administration:

Establish within 2 years scientifically based hours-of-service regulations that set limits on hours of service, provide predictable work and rest schedules, and consider circadian rhythms and human sleep and rest requirements. At a minimum, and as recommended by the National Transportation Safety Board in 1995, the revised regulations should also (a) require sufficient rest provisions to enable drivers to obtain at least 8 continuous hours of sleep after driving for 10 hours or being on duty for 15 hours, and (b) eliminate 49 CFR 395.1 paragraph (h), which allows drivers with sleeper berth equipment to cumulate the 8 hours of off-duty time in two separate periods. (H-99-19) (Supersedes H-95-1 and H-95-2)

To the Federal Railroad Administration:

Establish within 2 years scientifically based hours-of-service regulations that set limits on hours of service, provide predictable work and rest schedules, and consider circadian rhythms and human sleep and rest requirements. (R-99-2)

To the Research and Special Programs Administration:

Establish within 2 years scientifically based hours-of-service regulations that set limits on hours of service, provide predictable work and rest schedules, and consider circadian rhythms and human sleep and rest requirements. (P-99-12)

To the United States Coast Guard:

Establish within 2 years scientifically based hours-of-service regulations that set limits on hours of service, provide predictable work and rest schedules, and consider circadian rhythms and human sleep and rest requirements. (M-99-1)

Also as a result of this safety report, the National Transportation Safety Board reiterated the following safety recommendations to the Federal Aviation Administration:

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 take into consideration research findings on fatigue and sleep issues. 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 limitation of 14 CFR Part 121 or other appropriate regulations. (A-95-113)

Develop appropriate limitations on consecutive days on duty, and duty hours per duty period for flight crews engaged in scheduled and nonscheduled commercial flight operations, and apply consistent limitations in Alaska and the remainder of the United States. (A-95-125)

By the National Transportation Safety Board

James E. Hall
Chairman

Robert T. Francis II
Vice Chairman

John A. Hammerschmidt
Member

John Goglia
Member

George W. Black, Jr.
Member

Adopted: May 17, 1999

Fatigue-Related Recommendations Issued to the DOT:

Assess the potential safety risks associated with rotating pipeline controller shifts and establish industry guidelines for the development and implementation of pipeline controller work schedules that reduce the likelihood of accidents attributable to controller fatigue. (P-98-30)

Recipient(s)	Status
Research and Special Programs Administration	Open—Await Response

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Safety Board Document: Railroad Accident Report

Title: Atchison, Topeka and Santa Fe Railway Company (ATSF) Freight Trains ATSF 818 and ATSF 891 on the ATSF Railway Corona, California, November 7, 1990

Report Number: NTSB/RAR-91/03

Date Recommendation(s) Issued: August 23, 1991

Fatigue Cited as a Cause of or Contributing Factor to the Accident: Yes

Abstract:

This report explains the collision between two Atchison, Topeka and Santa Fe Railway freight trains in Corona, California, on November 7, 1990.

Fatigue-Related Conclusions:

The engineer of train 818 failed to stop his train on the Corona siding at the stop signal because he was asleep or in a microsleep brought about by chronic and acute fatigue.

The chronic and acute fatigue of the engineer of train 818 was a result of the irregularity and unpredictability of his work schedule.

Because of fatigue the conductor of train 818 either was asleep or experienced a microsleep as his train approached the stop signal on the west end of the Corona siding.

The brakeman of train 818 failed to take action to stop the train probably because she fell asleep as a result of fatigue.

The Atchison, Topeka and Santa Fe Railway Company did not have a policy or procedure in place to address the issue of an employee notifying the carrier of his or her lack of sufficient sleep.

Fatigue-Related Recommendations Issued to the DOT:

None

Safety Board Document:	Railroad Accident Report
Title:	Collision and Derailment of Norfolk Southern Train 188 With Norfolk Southern Train G-38 at Sugar Valley, Georgia, August 9, 1990
Report Number:	NTSB/RAR-91/02
Date Recommendation(s) Issued:	September 16, 1992
Fatigue Cited as a Cause of or Contributing Factor to the Accident:	Yes

Abstract:

This report explains the 1990 collision of two Norfolk Southern freight trains near Sugar Valley, Georgia.

Fatigue-Related Conclusions:

The engineer of train 188 had changed his work and rest routine just before the accident.

The engineer's failure to bring the train to a stop at the signal probably was caused by a microsleep or inattention due to distraction.

The conductor of train 188 was either distracted or fell asleep sometime after verifying the signal status at CP Davis.

The engineer of train 188 could have canceled the alerter system while he was asleep by a simple reflex action that he performed without conscious thought.

Fatigue-Related Recommendations Issued to the DOT:

In conjunction with the study of fatigue of train crewmembers, explore the parameters of an optimum alerter system for locomotives. (R-91-26)

Recipient(s)	Status
Federal Railroad Administration	Closed—Unacceptable Action

Safety Board Document: Railroad Accident Report

Title: Collision Involving Two New York City Subway Trains on the Williamsburg Bridge in Brooklyn, New York, June 5, 1995

Report Number: NTSB/RAR-96/03

Date Recommendation(s) Issued: September 11, 1996

Fatigue Cited as a Cause of or Contributing Factor to the Accident: Yes

Abstract:

This report explains the collision of two New York City Transit subway trains on the Williamsburg Bridge in Brooklyn, New York, on June 5, 1995. One person was killed and 69 people were treated at area hospitals for minor injuries sustained in this accident. The total estimated damages exceeded $2.3 million.

Fatigue-Related Conclusions:

The J train operator failed to take action to stop his train on the Williamsburg Bridge because he was asleep.

Fatigue-Related Recommendations Issued to the DOT:

In cooperation with the American Public Transit Association, develop a fatigue educational awareness program and distribute it to transit agencies to use in their fitness-for-duty training for supervisors and employees involved in safety-sensitive positions. (R-96-20)

Recipient(s)	Status
Federal Transit Administration	Closed—Acceptable Action

Safety Board Document: Special Investigation Report (Railroad)

Title: Steam Locomotive Firebox Explosion on the Gettysburg Railroad near Gardners, Pennsylvania, June 16, 1995

Report Number: NTSB/SIR-96/05

Date Recommendation(s) Issued: November 26, 1996

Fatigue Cited as a Cause of or Contributing Factor to the Accident: No

Abstract:

On June 16, 1995 the firebox crownsheet of Gettysburg Passenger Services, Inc., steam locomotive 12378 failed while the locomotive was pulling a six-car excursion train about 15 mph near Gardners, Pennsylvania. The failure resulted in an instantaneous release (explosion) of steam through the firebox door and into the locomotive cab, seriously burning the engineer and the two firemen. This accident illustrates the hazards that are always present in the operation of steam locomotives.

Fatigue-Related Conclusions:

Gettysburg Passenger Services, Inc., management was not aware of the Hours of Service Act.

Fatigue-Related Recommendations Issued to the DOT:

In cooperation with the Tourist Railway Association, Inc., promote awareness of and compliance with the Hours of Service Act. (R-96-56)

Recipient(s)	Status
Federal Railroad Administration	Open—Acceptable Response

Appendix C

Summary of Sleep and Circadian Rhythms

The summary in this appendix is an excerpt from information prepared by Dr. Mark Rosekind in April 1999 for the National Transportation Safety Board. The summary was adapted from material included in the Safety Board's report on its investigation of a 1993 aircraft accident. (Rosekind, Mark R. [NASA Ames Research Center]; Gregory, Kevin B. [Sterling Software]; Miller, Donna L. [Sterling Software]; and others. 1994. "Analysis of Crew Fatigue Factors in ATA Guantanamo Bay Aviation Accident." In: *Uncontrolled Collision With Terrain, American International Airways Flight 808, Douglas DC-8-61, N814CK, U.S. Naval Air Station in Guantanamo Bay, Cuba, August 18, 1993*. Aircraft Accident Report NTSB/AAR-94/04. Washington, DC: National Transportation Safety Board. pp. 133–144.)

Fatigue in Transportation: Physiological, Performance, and Safety Issues[1]

Mark R. Rosekind
Alertness Solutions
April 1999

Introduction

Maintaining safe transportation operations is a complex task. The undertaking must address a range of issues from the functioning of large systems to the individual human operator. For the foreseeable future, the human operator (pilot, driver, maintenance person, etc.), remains central to safe, efficient, and reliable transportation activities. Therefore, the importance of addressing human-related error, which accounts for at least 70% of transportation accidents, remains critical to maintaining and improving safety (Ref 1).

Fatigue, sleep loss, and circadian disruption created by transportation operations can degrade performance, alertness and safety. An extensive scientific literature exists that provides important physiological information about the human operator, which can be used to guide operations and policy. For example, there are human physiological requirements for sleep, predictable effects of sleep loss on performance and alertness, and patterns for recovery from sleep loss. Additionally, the circadian clock is a powerful modulator of human performance and alertness, and in transportation operations, it can be disrupted by night work, time zone changes, and day/night duty shifts. Scientific examination of these physiological considerations has documented a direct relationship to errors, accidents, and safety. This scientific information can provide important input to policy and regulatory considerations.

Managing fatigue in the complex and diverse transportation environment requires an integrated and multi-component approach. The complexity and diversity of operational requirements preclude a simple solution, and managing fatigue will benefit from addressing education, hours of service, strategies, technology, design, and research. The transportation industry has established a strong safety record by identifying and proactively addressing both substantiated and potential risks. Effectively managing fatigue in transportation operations offers the opportunity to further reduce risks and improve safety.

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[1]Adapted from the following references: (a) Rosekind MR, Gregory KB, Miller DL, Co EL, and Lebacqz JV. "Analysis of crew fatigue factors in AIA Guantanamo Bay Aviation Accident." *Uncontrolled Collision With Terrain, American International Airways Flight 808, Douglas DC-8-61, N814CK, U.S. Naval Air Station in Guantanamo Bay, Cuba, August 18, 1993.* Aircraft Accident Report NTSB/AAR-94/04. Washington, DC: National Transportation Safety Board, 1994. (b) Rosekind, MR, Neri, DF, and Dinges, DF. (1997). "From laboratory to flightdeck: Promoting operational alertness." *Fatigue and Duty Time Limitations—An International Review: Proceedings of the Royal Aeronautical Society, London, UK, 16 September 1997.*

This overview provides an introduction to the scientific foundation that exists regarding the physiology of and performance related to fatigue in transportation. It also examines the human physiological requirement for sleep and the functioning of the circadian clock.

The Biological Imperative: Human Sleep Need and the Circadian Clock

Human Sleep Requirements

Sleep is a vital physiological function. Historically, sleep has been viewed as a state when the human organism is turned off. However, scientific findings have clearly established that sleep is a complex, active physiological state that comprises different stages. On average, most people physiologically require about 8 hrs of sleep per night. When provided adequate time to sleep, humans can average about 8.25 to 8.5 hrs of physiological sleep (Refs 2,3). Laboratory studies use physiological measures (i.e., brain, eye, and muscle activity) of sleep quantity and quality and daytime sleepiness to determine the number of hours of sleep that provide an optimal level of waking alertness (Refs 4–6). It is important to distinguish this physiologically determined sleep requirement from both habitual and reported sleep amounts. Some studies have examined the reported amount of habitual sleep over time and other studies have collected one-time surveys inquiring about average sleep amounts. Overall, most adults report an average of about 7–7.5 hrs sleep per night (Ref 7). However, data obtained in controlled laboratory settings challenge whether this "reported" amount of sleep is sufficient for optimal levels of waking alertness. Studies have demonstrated that extending sleep beyond the reported 7–7.5 hrs of "usual" sleep significantly increases daytime alertness (Refs 3,8). The National Sleep Foundation commissioned a Gallop survey examining the report of daytime sleepiness in a random sample of 1,001 individuals. The findings demonstrated that 75% reported daytime sleepiness, with 32% of these reporting severe levels. Thirty-two percent reported that their sleepiness interfered with activities and 82% of the respondents believe that daytime sleepiness has a negative effect on their productivity (Ref 9).

These amounts are averages and there are individuals at both extremes of short and long sleep requirements. These sleep requirements change significantly with age (Ref 10). Younger individuals require more total sleep and this amount decreases to that needed by adults (although it is not the case that older people need less sleep than other adults). Sleep structure also changes with age (e.g., less deep sleep, more awakenings in older adults). In summary, humans physiologically require about 8 hrs of sleep, though they report usual sleep amounts of about 7–7.5 hrs. A majority of the adult population report daytime sleepiness, and when sleep is extended, there is a significant increase in alertness.

Effects of Sleep Loss

Sleep loss is common and can be acute or cumulative. In an acute situation, sleep loss can occur either totally or as a partial loss. Total sleep loss involves a completely missed sleep opportunity and continuous wakefulness for about 24 hrs or longer. Partial sleep loss occurs when sleep is obtained within a 24-hr period but in an amount that is reduced from the physiologically required amount or habitual total. Sleep loss also can

accumulate over time into a "sleep debt." For example, an individual who requires 8 hours of sleep and obtains only 6 hours is essentially sleep deprived by 2 hours. If the individual sleeps only 6 hours over 4 consecutive nights, then the 2-hour-per-night sleep loss would accumulate into an 8 hour sleep debt. Sleep loss, whether total or partial acute or cumulative, results in significantly degraded performance, alertness, and mood (Refs 7, 11–21).

The reduced human performance capability that results from total sleep loss is well documented (Refs 11–18). However, perhaps the most common occurrences in transportation operations are acute partial sleep loss and accumulation of a sleep debt. A review of the relevant scientific literature indicates that as little as two hours of sleep loss on just one occurrence can result in "impairment of performance and levels of alertness" (Ref 7). Therefore, an average individual with a physiological requirement of 8 hours sleep who obtains only 6 hrs of sleep may demonstrate significantly degraded waking performance and alertness. Cumulative sleep debt also significantly reduces alertness and performance (Refs 19–21). Studies have demonstrated that not only does the sleep loss accumulate but that the negative effects on waking performance and alertness also are cumulative and increase over time (Ref 20).

Performance decrements due to sleep loss can occur across diverse functions. For example, studies have demonstrated slowed reaction time, reduced vigilance, cognitive slowing, memory problems, time-on-task decrements, and optimum response decrements (e.g., Refs 13,14,16,18). Performance variability also increases with sleep loss. Therefore, overall performance can be significantly reduced with an increased variability or unevenness in responding (Ref 16). Consider that these findings occur in some of the simplest performance challenges, such as reaction time to a single stimulus or minimal choice memory task. These basic psychomotor and cognitive functions are the foundation for any task requiring complex, higher-order performance.

An important phenomenon, highly relevant to operational environments, is that there is a discrepancy between the subjective report of sleepiness/alertness and physiological measures. In general, individuals will report higher levels of alertness than indicated by physiological measures (Refs 22–24). Data from an international study of flight crews had an example where the highest subjective rating of alertness occurred at a time when physiologically the individual was falling asleep within 6 minutes (an indicator of severe sleepiness) (Ref 22). Likewise, subjective and physiological self-assessment of performance can differ significantly. The operational relevance of this phenomenon is clear. For example, an individual might report a low level of sleepiness or fatigue but could be carrying an accumulated sleep debt with a high level of associated physiological sleepiness. This individual, in an environment stripped of factors that conceal the underlying physiological sleepiness, would be susceptible to the occurrence of spontaneous, uncontrolled sleep episodes and to the performance decrements associated with sleep loss.

Recovery from Sleep Loss

When determining requirements for providing a recovery opportunity from sleep loss, two factors should be considered. First, when does the internal sleep architecture return to usual levels? Second, when do waking performance and alertness levels return to

their baseline? After sleep loss, recovery is not accomplished through an hour-for-hour restitution. Even after extremely prolonged wakefulness, initial recovery sleep may last only 12–15 hrs (Ref 25). Rather, recovery is accomplished through an increase in deep sleep (Non-Rapid-Eye-Movement or NREM slow wave sleep) observed starting on the first night of regular sleep (Refs 26–28). Generally, two nights of recovery sleep (slightly longer than an average night's sleep) are needed to resume a normal baseline sleep pattern (Refs 26,29), though this can be dependent on the duration of the continuous wakefulness. Also, typically, two nights of recovery sleep are needed to return to a normal baseline of waking performance and alertness (Refs 20,30), though this too can be dependent on the length of prior wakefulness (e.g., Ref 3).

The Circadian Clock

Besides sleep, the other major physiologic determinant of waking performance and alertness is the internal circadian clock (Refs 31–33). Circadian (*circa* = around, *dies* = day) rhythms fluctuate on a 24-hr cycle with peaks and troughs occurring in a regular pattern. These patterns are controlled by a circadian pacemaker located in the suprachiasmatic nucleus (SCN) in the brain. The SCN is the circadian timekeeper for a wide range of human functions. One of the most prominent is the 24-hr sleep/wake cycle programmed for a daytime period of consolidated wakefulness and a nighttime period of consolidated sleep. There are circadian patterns for cognitive and psychomotor performance, physiological activity (e.g., digestion, immune function, thermoregulation, DNA synthesis), alertness, and mood (Refs 34–38). Even birth and death have circadian patterns that peak during the night (see Ref 31).

Body temperature is often used as a marker of the internal circadian clock (sometimes referred to as the "hands of the clock"). The trough or low point of the clock is around 3 am to 5 am, with many functions demonstrating reduced levels from 12 am to 6 am. The lowest level of function (e.g., alertness, performance, subjective mood, temperature) occur within the 3 am to 5 am trough. Sleepiness has bimodal distribution (i.e., two peaks and two troughs each day), being most severe at 3 am to 5 am with a less marked but significant expression between roughly 3 pm to 5 pm. This afternoon increase in sleepiness occurs whether or not a meal has been consumed, though the meal may exacerbate the underlying sleepiness (Ref 39).

Zeitgebers ("time givers") are cues that synchronize circadian rhythms to their 24-hr pattern. To date, light has been demonstrated to be among the most powerful zeitgebers to synchronize the circadian pacemaker. Bright light can dramatically shift the phase of the human circadian clock when applied at responsive times in the 24-hr cycle (Refs 40–42). Without cues, the intrinsic rhythm of the clock is longer than 24 hrs. Generally, data have demonstrated a free-running pattern approximating 24.9 hrs, though recent findings suggest this may be closer to 24.2 hrs (Refs 31–33,43). An intrinsic period longer than 24 hrs provides an inherent tendency to support circadian delays (e.g., staying awake longer) and to oppose advances (e.g., trying to go to sleep earlier).

Moving to a new light/dark schedule, such as a shift to nightwork or a time zone change, can create internal and external desynchronization. These involve an internal

desynchrony among circadian rhythms and a discrepancy between internal circadian timing and external/environmental cues, respectively. The internal clock can take from several days to weeks for adjustment or, in some circumstances, not fully resynchronize at all. Scientific studies have demonstrated these findings in the laboratory and in field studies conducted during actual transportation operations (e.g., Refs 31–33, 44–54).

[Additional discussion is not included in this appendix.]