(1)	**Title of grant:**	Crew Alertness Management on the Flight Deck: Cognitive and Vigilance Performance
(2)	**Type of report:**	Summary of Research
(3)	**Name of principal investigator:**	David F. Dinges, Ph.D.
(4)	**Period covered by the report:**	February 1, 1989 to October 31, 1998
(5)	**Name and address of the recipient's institution:**	Institute for Experimental Psychiatry Research Foundation 290 Sycamore Avenue Merion Station, PA 19066
(6)	**Grant number:**	NCC-2-599

This project had three broad goals: (1) to identify environmental and organismic risks to performance of long-haul cockpit crews; (2) to assess how cognitive and psychomotor vigilance performance, and subjective measures of alertness, were affected by work-rest schedules typical of long-haul cockpit crews; and (3) to determine the alertness-promoting effectiveness of behavioral and technological countermeasures to fatigue on the flight deck. During the course of the research, a number of studies were completed in cooperation with the *NASA Ames Fatigue Countermeasures Program*. The publications emerging from this project are listed in a bibliography in the appendix. Progress toward these goals will be summarized below according to the period in which it was accomplished.

1989-1992: During the initial years of this project, we participated in the design, implementation, data acquisition, and data analyses of the NASA Cockpit Rest Study. The Cockpit Rest Study was the first to systematically involve an experimental test of a sleep-based fatigue countermeasure (i.e., a 30-minute planned nap in the cockpit seat) in an actual long-haul flight environment. It involved physiological and performance monitoring of 21 long-haul commercial cockpit crewmembers during four trans-Pacific flight legs. The results from this study demonstrated that objective laboratory based, portable tests of performance that we developed (i.e., the psychomotor vigilance task or PVT), could be used to document fatigue during flight and its relief by a nap countermeasure. The entire Cockpit Rest study and results were written up, and formed the basis for the FAA to evaluate cockpit rest and issue an advisory circular on it. Other aspects of the data from the Cockpit Rest Study have also been published.

1992-1993: In parallel with related work described above and below, we assisted the NASA-Ames Fatigue Countermeasures Program in planning and initiating a study of the effects of shift work (especially night work) on alertness, performance, and circadian adjustment of NASA Johnson Space Center ground controllers during space shuttle missions. A study was conducted in which we generated forms and booklets for, and analyzed, over 24,000 pages of self-reported alertness and cognitive performance data from JSC personnel during an STS mission between December and January of 1992-3. The findings were integrated with those of the NASA Ames Fatigue Countermeasures Program and a briefing was provided to Johnson Space Center personnel.

We also completed implementation into NASA Ames Fatigue Countermeasures Program protocols of three short-duration neurobehavioral probes: (1) the portable psychomotor vigilance (PVT-192) test for assessing sustained attention in flight crews; (2) the probed-recall memory (PRM) test for assessing working memory; and (3) subjective performance and effort ratings designed to improve evaluation of subjective impressions of fatigue.

1993-1994: We participated in completion of phase I of NASA Ames' studies of pilots' sleep in aircraft bunks during flights, which involved completion of a survey by more than 8,000 long-haul cockpit crew members. We participated in the development of the survey instrument to assess the perception of sleep by long-haul flight crews in two environments: while at home and in onboard crew rest facilities during long-haul flight operations. This study was successfully completed in 1994. We participated in evaluation of the results, specific analyses of the data, and interpretation of the findings.

In 1993, we also performed data reduction and analyses on physiological and performance variables from the P.I.'s NIH-sponsored laboratory study of the effects of 64 hr of sleep loss on healthy adults. In this study the NASA Ames Fatigue Countermeasures Program participated by acquiring the ambulatory EEG-EOG data in order to identify the physiological correlates of fatigue. For comparison purposes, the PVT performance results from this study, as well as the wrist actigraphy and related subjective results from the study were combined in a database and compared to the results on these measures from the NASA Ames Cockpit Rest Study. During 1994, data from three newly completed protocols were added to the database. Analyses were conducted to identify the range of individual differences in PVT performance lapsing during a night without sleep. This collaborative database served as a key resource in the validation of specific physiological and behavioral dependent variables to be used in future NASA fatigue countermeasure studies.

In addition, we also assisted the NASA Ames Fatigue Countermeasures Program in completion of a study to determine whether miniaturized psychomotor vigilance performance devices and rest-activity monitors could be employed in aviation field protocols in which no observer was present. A total of 15 long-haul flight crew members were followed for a period of 7 days, which involved two augmented flights of approximately 11 hours duration.

1994-1995: We collaborated with NASA Ames Fatigue Countermeasures Program in a major survey entitled Studies of Regional, Commuter, and Corporate Flight Operations. Data acquisition on the regional project was completed in 1995. We participated in development of the survey instruments used in these studies. More than 2,000 pilots and officials from regional, commuter, and corporate aviation sectors completed the surveys.

In this period, we also completed a study of the reliability of individual differences in performance-impairing reactions to night operations and sleep loss. This focused on data analyses of PVT performance data acquired from various laboratory and field studies of fatigue conducted by our laboratory and the NASA Ames Fatigue Countermeasures Program. During 1995, preliminary analyses revealed that approximately 10-20% of healthy subjects (depending on the cutoff criterion) had a severe PVT performance decrement on night flights. Subsequent analyses revealed that this decrement was a more-or-less stable characteristic of subjects, suggesting that some flight crew members are consistently prone to severe vigilance performance impairment during normal nocturnal operations.

We also completed a laboratory study of the Effects of Sleep Restriction on Performance. Cumulative sleep loss has consistently been found in NASA studies of transmeridian flight crews. In an effort to determine the nature of the mathematical growth of performance deficits accruing from cumulative sleep loss, during 1995, we completed a laboratory study (NIH funded) of daytime performance in 16 healthy subjects restricted to 5 hours sleep a night for 7 consecutive nights. These results were compared to those observed from NASA's field studies of long-haul pilots. These findings were not entirely predicted by current biomathematical models of alertness, and suggest that the cumulative deficits in performance from sustained sleep restriction of the kind experienced by some flight crew members may escalate to serious levels.

We participated in the design and measurement implementation of the Augmented Long-Haul Field Study, which focused on the physiological sleep of cockpit crews in crew rest facilities during actual flight operations. We provided the equipment, protocols, and some manpower for collection of data on flight crews' PVT performance and cognitive performances, subjective activation, and wrist activity monitoring. The NASA Ames Fatigue Countermeasures Program initiated this study in 1995, and significant progress was made on data acquisition. Extensive probed performance data (i.e., PVT and PRM tasks) were gathered (along with physiological and environmental data) on a total of 39 cockpit crew members: 17 flight crew members in 747-400 aircraft; 8 flight crew members in 747-200 aircraft; 11 flight crew members in 767 aircraft; and 3 flight crew members in long-haul corporate aircraft.

1995-1996: Data analyses of performance parameters and subjective alertness measures from the Augmented Long-Haul Study were completed in 1996 on 39 cockpit crew members. Data were evaluated for the effects of sleep in the crew rest facilities, flight leg, time of day, and aircraft type/operation. The findings were integrated with physiological, behavioral, and environmental variables analyzed at NASA. Performance variables were compared to equivalent measures from the NASA Cockpit Rest Study, and from the P.I.'s various laboratory experiments on the effects on performance capability of night work, as well as partial and total sleep deprivation. These comparisons provide a calibration of the level of neurobehavioral functioning across NASA studies.

During this period we also collaborated with the NASA Ames Fatigue Countermeasures Program in an examination of the scientific basis for federal regulations governing work-rest schedules of flight crews. The document was used by the FAA as one of a number of key sources of information in its Notice for Proposed Rule Making to amend existing regulations to establish one set of duty period limitations, flight time limitations, and rest requirements for flight crew members engaged in air transportation.

1996-1998: In 1997, the P.I. participated in a roundtable discussion and meeting sponsored by the Transportation Research Board of the National Academy of Sciences regarding the scientific basis for proscriptive work-rest scheduling in transportation modes. This work was completed in 1998 with the publication of a review of fatigue countermeasures relative to flight and duty time considerations.

As a prelude to a NASA Ames Fatigue Countermeasures Program study of activity breaks as fatigue countermeasures during long-haul night flights, our laboratory performed a study demonstrating that even mild forms of activity (e.g., postural changes) and mild stimulation (e.g., social and cognitive) could markedly enhance alertness and prevent performance lapses, especially at the low point in the body's endogenous circadian rhythm during night operations. The results of our study

helped the Fatigue Countermeasures Program to design and implement a study in the NASA Ames 747-400 cockpit simulator to measure the effects of brief activity breaks on the performance and alertness in 28 flight crew members during night flights. We provided conceptual, statistical, and logistic input to the study design and implementation, as well as equipment, manpower, and protocols for collection of data on flight crews' psychomotor vigilance and cognitive performances, and subjective activation. A total of 28 pilots were studied during a simulated night flight. The results of this study are currently being prepared for publication.

The 747-400 simulator study on the effects of activity breaks also served as the first systematic effort to objectively record pilot alertness levels during flights using video of the face and eyes. In laboratory research we performed during this period for the U.S. Department of Transportation and Air Force Office of Scientific Research, we tested the extent to which 6 new on-line, miniaturized fatigue detection technologies could reliably track alert and fatigued psychomotor vigilance performance. This included two EEG algorithms, two eye-blink monitors, one head position sensor array, and one video-based system for tracking slow eyelid closures. Only the latter technology proved reliable in all subjects at all times. This technology was deployed in the NASA Ames Fatigue Countermeasures Program study of activity breaks as fatigue countermeasures during long-haul night flights. The results provided the first data on on-line continuous monitoring of flight crew alertness. Boeing Commercial Airplane Group has shown very high interest in pursuing these discoveries to develop an on-board, objective crew alertness management system.

In summary, we believe that the outline of our accomplishments in this project amply illustrate that we have achieved our goal of helping to provide the NASA Ames Fatigue Countermeasures Program with novel, scientifically valid behavioral, biological, and technological strategies and techniques for enhancing physiological alertness, performance, and safety in flight crews. In addition to actively performing research for and with the NASA Ames Fatigue Countermeasures Program during the past 9 years, our laboratory has also provided the program with the detailed results of studies we have completed for other federal agencies (e.g., NIH, DOD, DOT) on the effects of novel fatigue countermeasures that have been validated to work in controlled laboratory experiments we have performed (e.g., our development of "prophylactic napping" led to NASA's demonstration of "planned cockpit rest" as an effective fatigue countermeasure). We have also been able to inform the Program of interventions that have not proven to be effective in controlled experiments, and therefore saved the Program the expense of carrying out such studies. Finally, during the latter years of this project we have been involved in fatigue countermeasure work for long-duration human space flight and the manned mission to Mars. This work directly connects to many of the issues being addressed with the Fatigue Countermeasures Program at Ames. Dr. Dinges is a funded investigator and Associate Team Director on the Human Performance Factors, Sleep, and Chronobiology Team of the National Space Biomedical Research Institute, supported by NASA. He also serves on the Scientific Working Group for the Human Research Facility for the International Space Station, and together with Dr. Neri at NASA-Ames Research Center, he is part of a new working group on fatigue and performance monitoring in astronauts.

Negative Inventions Statement: No inventions came out of this research.

Appendix
Bibliography

Publications relevant to work during the past 9 years:

Dinges, D.F., Graeber, R.C.: Crew fatigue monitoring. Flight Safety Digest Supplement, 65-75, 1989.

Dinges, D.F. & Graeber, R.C.: Crew fatigue monitoring. In Proceedings of the Second Regional Workshop on Crew Performance Monitoring and Training, FSF, 1989.

Dinges, D.F.: Crew rest and sleep deprivation. 35th Corporate Aviation Safety Seminar Proceedings, Flight Safety Foundation, 70-77, 1990.

Dinges, D.F.: The nature of subtle fatigue effects in long-haul crews. 43rd International Aviation Safety Seminar, Flight Safety Foundation, 258-267, 1990.

Graeber, R.C., Dinges, D.F.: Flight crew fatigue: underlying causes & operational factors. The 1st Regional Aviation Safety Conference, Flight Safety Foundation, 161-174, 1990.

Graeber, R.C., Connell, L.J., Rosekind, M.R., Dinges, D.F.: Cockpit napping. ICAO Journal, 6-10, Oct. 1990.

Dinges, D.F.: What management should know about fatigue in corporate aviation safety. 36th Corporate Aviation Safety Seminar, Flight Safety Foundation, 160-166, 1991.

Dinges, D.F., Connell, L.J., Rosekind, M.R., Graeber, R.C.: Preplanned cockpit rest: Effects on vigilance performance in long-haul flight crews. (Paper presented at the 62nd Annual Scientific Meeting of the Aerospace Medical Association, Cincinnati), May 1991.

Dinges, D.F., Kribbs, N.B.: Performing while sleepy: Effects of experimentally-induced sleepiness (Chapter 4) in Monk, T.H. (Ed.) Sleep, Sleepiness and Performance, John Wiley and Sons, Ltd., Chichester, United Kingdom, pp. 97-128, 1991.

Dinges, D.F., Kribbs, N.B., Gillen, K.A.: The nature of subtle fatigue effects in long-haul crews: Contexts and countermeasures. (Paper presented at the 6th International Symposium on Aviation Psychology, Columbus), May 1991.

Rosekind, M.R., Gander, P.H., Dinges, D.F.: Alertness management in flight operations: Strategic napping. SAE Technical Paper, No. 912138:1-12, 1991.

Dinges, D.F.: Probing the limits of functional capability: The effects of sleep loss on short-duration tasks (Chapter 12) in R.J. Broughton and R. Ogilvie (Eds.) Sleep, Arousal and Performance. Birkhauser-Boston, Inc., Cambridge, 1992, pp. 176-188.

Rosekind, M.R., Gander, P.H., Miller, D.L., Gregory, K.B., McNally, K.L., Smith, R.M., & Lebacqz, J.V. NASA Ames Fatigue Countermeasures Program. FAA Aviation Safety Journal, 1993.

Dinges, D., Gillen, K., Ott, G.: Accidents, sleepiness and work hours -- a review. Stress Research Reports, No. 248 (Presented at the "Work Hours, Sleepiness and Accidents" Symposium, Karolinska Institute, Stockholm, Sweden), Sept 1994.

Kelly, S.M., Rosekind, M.R., Dinges, D.F., Miller, D.L., Gillen, K.A., Gregory, K.B., Aguilar, R.D., Smith, R.M.: Flight controller alertness and performance during MOD shiftwork operations. SOAR '93 NASA Conference Publication No. 3240, 7th Annual Workshop on Space, Operations, Applications, and Research, 1994.

Rosekind, M.R., Graeber, R.C., Dinges, D.F., Connell, L.J., Rountree, M., Gillen, K.A.: Crew factors in flight operations: IX. Effects of cockpit rest on crew performance and alertness in long-haul operations. NASA Technical Memorandum Report No. 103884, 252, 1994.

Dinges, D.F., Douglas, S.D., Zaugg, L., Campbell, D.E., McMann, J.M., Whitehouse, W.G., Orne, E.C., Kapoor, S.C., Icaza, E., Orne, M.T.: Leukocytosis and natural killer cell function parallel neurobehavioral fatigue induced by 64 h of sleep deprivation. The Journal of Clinical Investigation 93:1930-1939, May 1994.

Dinges, D.F.: An overview of sleepiness and accidents. Journal of Sleep Research 4(2):4-11, 1995.

Dinges, D.F.: Performance effects of fatigue. Proceedings: Managing Fatigue in Transportation: Promoting Safety and Productivity, 41-46, 1995.

Dinges, D.F.: Napping Strategies. Proceedings: Managing Fatigue in Transportation: Promoting Safety and Productivity, 47-51, 1995.

Dinges, D.F.: Technology / Scheduling Approaches. Proceedings: Managing Fatigue in Transportation: Promoting Safety and Productivity, 53-58, 1995.

Dinges, D.F.: Validation of psychophysiological monitors. Proceedings: Technical Conference on Enhancing Commercial Motor Vehicle Driver Vigilance, 35-41, 1996.

Dinges, D.F., Graeber, R.C., Rosekind, M.R., Samel, A., Wegmann, H.M.: Principles and guidelines for duty and rest scheduling in commercial aviation. NASA Technical Memorandum Report No. 110404, 1-10, 1996.

Gary, K.A., Winokur, A., Douglas, S.D., Kapoor, S., Zaugg, L., Dinges, D.F.: Total sleep deprivation and the thyroid axis: effects of sleep and waking activity. Aviation, Space, and Environmental Medicine 67(6):513-519, 1996.

Dinges, D.F., Pack, F., Williams, K., Gillen, K.A., Powell, J.W., Ott, G.E., Aptowicz, C., Pack, A.I.: Cumulative sleepiness, mood disturbance, and psychomotor vigilance performance decrements during a week of sleep restricted to 4-5 hours per night. Sleep 20(4):267-277, 1997.

Dinges, D.F.: The promise and challenges of technologies for monitoring operator vigilance. Proceedings: An International Perspective on Managing Fatigue in Transportation: What We Know and Promising New Directions for Reducing the Risks, 77-86, 1997.

Rosekind, M.R., Neri, D.F., & Dinges, D.F.: From laboratory to flightdeck: promoting operational alertness. Proceedings: The Royal Aeronautical Society's Symposium on Fatigue and Duty Time Limitations-An International Review, September 16, London, UK, 7.1-7.14, 1997.

Smith-Coggins, R., Rosekind, M.R., Buccino, K.R., Dinges, D.F., Moser, R.P.: Rotating shiftwork schedules: Can we enhance physician adaptation to night shifts? Academic Emergency Medicine 4:951-961, 1997.

Dinges, D.F., Mallis, M.M.: Managing fatigue by drowsiness detection: Can technological promises be realized? In Hartley, L. (Ed) Managing Fatigue in Transportation. Pergamon, Oxford, pp. 209-229, 1998.

Dinges, D.F., Mallis, M., Maislin, G., Powell, J.W.: Evaluation of techniques for ocular measurement as an index of fatigue and as the basis for alertness management. U.S. Department of Transportation,104pp, Report No. DOT HS 808 76, 1998.

Dinges, D.F., Ott, G.E., Gillen, K.A., Carlin, M.M., Orne, E.C., Powell, J.W., Kribbs, N.B., Rosekind, M.R., Orne, M.T.: Homeostatic and circadian interaction in control of waking neurobehavioral functions during total sleep deprivation. in preparation.

Abstracts relevant to work during the past 9 years:

Dinges, D.F., Graeber, R.C., Connell, L.J., Rosekind, M.R., Powell, J.W.: Fatigue-related reaction time performance in long-haul flight crews. Sleep Research 19:117, 1990.

Rosekind, M.R., Townsend, B., Roundtree, M., Connell, L., Yost, D., Graeber, R.C., Spinweber, C., Dinges, D.F., Dement, W.C.: Modification of the Medilog 9000-II recorder to reduce 400Hz noise in the cockpit environment. Sleep Research 19:377, 1990.

Dinges, D.F., Connell, L.J., Rosekind, M.R., Gillen, K.A., Kribbs, N.B., & Graeber, R.C.: Effects of cockpit naps and 24-hr layovers on sleep debt in long-haul transmeridian flight crews. Sleep Research 20: 406, 1991.

Dinges, D.F., Kribbs, N.B., Steinberg, K.N., & Powell, J.W.:Do we lose the willingness to perform during sleep deprivation? Sleep Research 21:318, 1992.

Dinges, D.F., Rosekind, M.R., Connell, L.J., Graeber, R.C., Gillen, K.A.: Eastbound night flights vs. westbound day flights: Directionally dependent effects on flight crew layover sleep. Sleep Research 21:118, 1992.

Dinges, D.F., Douglas, S.D., Zaugg, L., Campbell, D., Whitehouse, W., McMann, J.M., Icaza, E., Reber, D., Haupt, B., Laizner, A., Carlin, M., Ukpah, P., Orne, E.C., Getsy, J., Orne, M.T.: Human immune function prior to, during, and following recovery from 64 hours without sleep. Sleep Research 22:329, 1993.

Maislin, G., Kribbs, N.B., Pack, A.I., Smith, P.L., Schwartz, A.R., Getsy, J.E., Kline, L.R., Schwab, R.J., Petrof, B.J., Dinges, D.F.: A survey screen for likelihood ratio prediction of apnea. Sleep Research 22:369, 1993.

Rosekind, M.R., Dinges, D.F., Gregory, K., Gillen, K., Smith, R., Powell, J., Miller, D.L.: Estimating nap sleep in operational settings: A comparison of actigraphy vs ambulatory polysomnography. Sleep Research 22:380, 1993.

Dinges, D.F., Douglas, S.D., Zaugg, L., Campbell, D., Whitehouse, W., McMann, J.M., Icaza, E., Reber, D., Haupt, B., Laizner, A., Carlin, M., Ukpah, P., Orne, E.C., Getsy, J., & Orne, M.T.:Human immune function prior to, during, and following recovery from 64 hours without sleep. Sleep Research 22:329, 1993.

Dinges, D.F., Kribbs, N.B., Bates, B.L., & Carlin, M.C.:A very brief probed-recall memory task: Sensitivity to sleep loss. Sleep Research 22:330, 1993.

Rosekind, M.R., Dinges, D.F., Gregory, K., Gillen, K., Smith, R., Powell, J., & Miller, D.L.: Estimating nap sleep in operational settings: A comparison of actigraphy vs ambulatory polysomnography. Sleep Research 22:380, 1993.

Dinges, D.F., Gillen, K.A., Carlin, M.M., Ott, G.E., Orne, E.C., Orne, M.T.: Discriminating sleepiness by fatiguability on a psychomotor vigilance task. Sleep Research 23:407, 1994.

Dinges, D.F., Pack, F., Gillen, K.A., Powell, J.W., Kribbs, N.B., Ott, G.E., Pack, A.I.: Cumulative effects of acute partial sleep deprivation on PVT Lapses and SSS ratings. Sleep Research 23:408, 1994.

Dinges, D.F., Gillen, K.A., Powell, J.W., Pack, F., Williams, K.S., Kribbs, N.B., Orne, E.C., Carlin, M.M., Ott, G.E., Rosekind, M.R., Orne, M.T., & Pack, A.I.: Mood reports during total and partial sleep deprivation: Is anger inevitable? Sleep Research, 24:441, 1995.

Dinges, D.F., Ott, G.E., Gillen, K.A., Orne, E.C., Powell, J.W., Carlin, M.M., Kribbs, N.B., Rosekind, M.R., Orne, M.T.: Homeostatic and circadian control of waking during sleep deprivation. Sleep Research 24:442, 1995.

Rosekind, M.R., Miller, D.L., Gregory, K.B., Dinges, D.F.: Flight crew sleep in long-haul aircraft bunk facilities: survey results. Sleep Research 24:112, 1995.

Dijkman, M., Sachs, N., Levine, E., Mallis, M., Carlin, M.M., Gillen, K.A., Powell, J.W., Samuel, S., Mullington, J., Rosekind, M.R., Dinges, D.F.: Effects of reduced stimulation on neurobehavioral alertness depend on circadian phase during human sleep deprivation. Sleep Research 26:265, 1997.

Rosekind, M.R., Gregory, K.B. Miller, D.L., Oyung, R.L., Neri, D.F., Dinges, D.F.: Sleep quantity and quality of augmented long-haul flight crews in on-board crew rest facilities. Sleep Research 26:41, 1997.

Rowland, L., Thorne, D., Balkin, T., Sing, H., Wesensten, N., Redmond, D., Johnson, D., Anderson, A., Cephus, R., Hall, S., Thomas, M., Powell, J.W., Dinges, D.F., Belenky, G.: The effects of four different sleep-wake cycles on psychomotor vigilance. Sleep Research 26:627, 1997.

Wyatt, J.K., Dijk, D-J., Ronda, J.M., Jewett, M.E., Powell, J.W., Dinges, D.F., Czeisler, C.A.: Interaction of circadian- and sleep/wake homeostatic-processes modulate psychomotor vigilance test (PVT) performance. Sleep Research 26:759, 1997.

Dinges, D.F., Mallis, M.M., Powell, J.W., Maislin, G.: Technological solutions to fatigue management: Can operator performance be predicted by biobehavioral monitors. Aviation, Space, and Environmental Medicine, 69(3):169, 1998.

Kuo, A., Carlin, M.M., Powell, J.W., Dinges, D.F.: Chronic restriction of sleep to 4 hours per night for 14 nights changes performance linearly but not subjective sleepiness. Sleep 21S:169.J, 1998.

Johnson, D., Thorne, D., Rowland, L., Balkin, T., Sing, H., Thomas, M., Wesensten, N., Redmond, D., Russo, M., Welsh, A., Aladdin, R., Cephus, R., Hall, S., Powell, J., Dinges, D., Belenky, G.: The effects of partial sleep deprivation on psychomotor vigilance. Sleep 21S:137.I, 1998.

Mallis, M.M., Powell, J.W., Gilllen, K.A., Konowal, N., Martino, M., Dinges, D.F.: Technological solutions to fatigue management: A controlled double-blind validation trial on six technologies. Aviation, Space, and Environmental Medicine, 69(3):192, 1998.

Mallis, M.M., Maislin, G., Powell, J.W., Staszewski, J.J., Grace, R., Dinges, D.F.: New drowsiness detection technologies testing their validity to track hypovigilance. Sleep 21S:172.N, 1998.

Konowal, N.M., Van Dongen, H.P., Powell, J.W., Mallis, M.M., Dinges, D.F.: Determinants of microsleeps during experimental sleep deprivation, Sleep, in press.

Mallis, M.M., Neri, D.F., Oyung, R.L., Dinged, D.F.: Effectiveness of in-flight activity breaks as fatigue countermeasures during a simulated night flight? Aviation, Space and Environmental Medicine, in press.

Neri, D.F., Mallis, M.M., Oyung, R.L., Dinges, D.F.: Do activity breaks reduce sleepiness in pilots during a night flight? Sleep, in press.

Media relevant to work during the past 9 years:

None.