2003

Working the Nightshift on the USS STENNIS: Implications for Enhancing Warfighter Effectiveness

Miller, N.L.

Miller, N.L. and Nguyen, J.L., "Working the Nightshift on the USS STENNIS: Implications for Enhancing Warfighter Effectiveness," Proceedings of the Human Systems Integration Symposium, June 2003.
http://hdl.handle.net/10945/36518

Dr. Nita Lewis Miller and Lt. John Nguyen, USN

Working the Nightshift on the *USS John C. Stennis*: Implications for Enhancing Warfighter Effectiveness

ABSTRACT

For over three decades, the U.S. Navy has employed a unique approach to fatigue management for carrier operations. This technique uses two aircraft carriers and allows them to share the responsibility of around-the-clock flight operations. Crewmembers aboard one carrier work primarily the day shift while crewmembers aboard the other carrier work the night shift. U.S. Naval forces, carrying out air strikes against targets in Afghanistan during *Operation Enduring Freedom*, recently employed such a procedure to support 24-hour air operations. Beginning January 2002, primary responsibility for carrier-based night air operations was assigned to the *USS John C. Stennis*.

A major concern was whether sailors required to work night shift had adjusted to this inverted work/rest cycle and were getting adequate sleep. The results presented here indicate that reversing the work/rest cycle had a profound effect on the sleep patterns and the reported fatigue levels of the sailors. A large number of the participants in this study reported that they had not adjusted to this reversed schedule, even after being on the schedule for over 30 days.

There were also unexpected differences in the quality and quantity of sleep between those working topside compared to those working belowdecks. The study also discusses how improved sleep and schedule management can enhance human performance.

INTRODUCTION

The pace of modern warfare has led to a fundamental shift in the requirements placed on the human combatants. As recent events in the Iraqi conflict have demonstrated, the operational tempo of modern warfare affords fewer opportunities for the warfighter to get sleep. The 24/7 nature of today's combat provides little chance to withdraw from the battle to get high quality rest and recuperative sleep. Tragically, along with the increasing demands and decreased rest and sleep available to today's warfighter, this reduced opportunity for sleep may be associated with incidents of fratricide and errors. It is increasingly important to assure high levels of human performance in this complex and dangerous environment.

BACKGROUND

The human circadian rhythm is a well-documented phenomenon. It can be thought of as an internal body clock that is synchronized to approximately a 24-hour period. Many physiological functions exhibit circadian rhythms, (for example, body temperature, hormone secretion, heart rate, blood pressure, respiration, and digestion) all vary over the course of a day (Naitoh, Kelly, and Englund, 1989). Cognitive processes also show a predictable circadian variation (Gillooly, Smolensky, Albright, His, and Thorne, 1990, Krueger, 1990; Colquhoun, 1982.) During the very early morning hours, approximately 0200 to 0400, (the "circadian trough"), studies have shown that human vigilance, productivity, and attention spans plunge significantly. Not surprisingly, accident rates are much higher during this circadian nadir than at other times of the day (Mitler, Carskadon, Czeisler, Dement, Dinges, and Graeber, 1988; Harrison and Horne, 2000).

Circadian rhythms can be disrupted when working and sleeping at unconventional hours. During those times, a person may try

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
MAY 2003	**N/A**	**-**

4. TITLE AND SUBTITLE
Working the Nightshift on the USS John C. Stennis: Implications for Enhancing Warfighter Effectiveness

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Naval Postgraduate School Operations Research Department Monterey, CA 93943

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES
Proceedings of the Aerospace Medical Association, May 2003

14. ABSTRACT
see report

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**SAR**	**8**	

to stay at a high level of alertness while their body is demanding sleep. As a result, "circadian desynchronosis" may occur where the diurnal nature of the human body is disrupted (Griffith, 1993). Prolonged exposure to such sleep regimens can lead to increased fatigue, mood alteration, performance decrements, and long-term health consequences (Costa, 1996). For animals and humans who are subjected to extreme sleep deprivation, the result is death (Coren, 1996).

While it is possible for the circadian rhythms of an individual to adjust to unusual work routines, the process is slow and is inhibited by the presence of social and environmental "zeitgebers" or timekeepers (Monk, 1989). One such zeitgeber is light, either natural or artificial. Exposure to light inhibits the release of melatonin, a naturally occurring hormone released by the pineal gland, which has been shown to promote sleep in humans (Goh, Tong, Low, and Lee, 2001).

In the civilian community, it is well known that certain individuals find it difficult (or even impossible) to adjust to night shift work. Although U.S. Navy crewmembers may be required to work night duty, sailors are not selected for carrier duty on the basis of their ability to adapt to shift work operations. In addition, their exposure to daylight prior to their major sleep period is not controlled.

Crewmembers and Air Wing 9 of the *USS John C. Stennis* (CVN-74) departed on 12 November 2001, knowing that their deployment to the Arabian Sea was going to be far from routine. Their mission was to support the war in Afghanistan, code name *Operation Enduring Freedom*. During combat, aircrew members are required to fly a tremendous number of night missions and their circadian rhythms are frequently disrupted by these "night carrier operations." Recognizing this problem, the *USS John C. Stennis* adjusted the work and sleep schedules of her entire crew. In order to accommodate the need for night operations by the flight crew and to demonstrate support for this requirement, the work schedule of the entire ship's company was shifted to nights. This schedule required the crewmembers to get up at 1800 for breakfast and other daily routines, while working throughout the night and early hours until 1000 when their duty day concluded.

The objective of this research was to evaluate the circadian rhythms of sailors aboard *USS John C. Stennis* who were experiencing an inverted work/rest schedule. The underlying question was whether sailors were getting appropriate rest on this inverted work/rest schedule.

METHOD

Objective estimates of sleep quality and duration were obtained using a wrist activity monitor (brand name *Actigraph*™), which recorded physical activity. A total of 72 hours of continuous data were collected using measures of sleep and physical activity (actigraphy), as well as oral temperatures, reported sleepiness, and self-reported activity levels (obtained every three hours) during participants' waking hours. Demographic data, sleep habits, and concerns over the inverted work/sleep schedule were obtained from participants.

Participants

Thirty-three enlisted crewmembers aboard the *USS John C. Stennis* participated in the study. During combat flight operations, each watchstander is critical to the success or failure to the ship's mission. For this reason, efforts were made to recruit watchstanders from different departments aboard the ship. The final sample was made up of ship's force and air wing personnel from 10 different departments. Of the 33 original participants (27 males, 6 females), valid data were obtained from 28 individuals (22 males, 6 females).

Equipment

A demographic survey was developed by the researchers and included questions pertaining to age, rank, gender, nicotine use, caffeine consumption, military and education experience and current duty assignment. Wrist activity monitors (Actigraph™) were used to collect objective estimates of sleep quality and duration. (See FIGURE 1)

FIGURE 1. AMI Actigraph

Data from the wrist activity monitor can be displayed and managed graphically using software such as Action-W©, commercially available through AMI, Inc. Using the Action-W software, the following calculations were made for each participant in the study: average sleep per day, average duration of sleep episode, total amount of sleep, and total number of sleep episodes in the 72-hour period.

The Fatigue Avoidance Scheduling Tool (FAST) package was used to further analyze the actigraphy data. FAST is based on the human fatigue model selected by the Department of Defense, called the Sleep and Fatigue Task Effectiveness model (SAFTE) (Hursh, 2001). The FAST program and the SAFTE Model are patented by Dr. Steve Hursh of SAIC and are used to predict cognitive effectiveness from a given individual's actigraph recording (Hursh, et al. (in press); Eddy, D.R. and Hursh, S.R., 2002).

Other equipment used in the study included oral thermometers and paper logs for recording oral temperature, sleepiness rating, sleep quality and timing of the work schedule.

Procedures

Volunteers aboard the *USS John C. Stennis* were briefed on the purpose of the study and signed consent forms. They were then issued actigraphs, oral thermometers, a paper log for recording their temperatures, their sleep and work times, and their sleepiness ratings. Participants were asked to record their temperature and their sleepiness rating every three hours while awake. They were also asked to indicate their work and sleep times on the paper log and to rate the quality of each sleep period after awakening. At the end of 72 hours, all actigraphs and paper data logs were collected. The data were imported into the FAST program to compute predicted effectiveness for each individual.

RESULTS

The results of the study are divided into two sections. The first section addresses self-reported data and demographic trends. The second section gives the results of the actigraphy-derived sleep estimates and relates them to work setting.

Self-reported Adjustment to Schedule

Thirteen (46.4%) of the 28 participants reported that they were not fully adjusted, even though over 30 days had passed since the *USS Stennis* switched to the night schedule. Females appeared to have a lower rate of adjustment (n=2; 33.3%) than males (n=13; 59.1%), although this difference was not statistically significant. (See TABLE 1.)

Have you ever completely adjusted?

	Male	Female	Total
No	9	4	13
Yes	13	2	15
	22	6	28

TABLE 1. Reported Adjustment to Schedule by Gender

Topside/Belowdecks Working Condition
Of the 28 participants, 12 were classified as working topside, and of those, 9 (75%) were male (see TABLE 2). Females were equally split across work assignments, with 50% working topside and 50% working belowdecks.

Duty location:

	Male	Female	Total
Topside	9	3	12
Belowdeck	13	3	16
	22	6	28

TABLE 2. Duty Location by Gender

ACTIGRAPHY DATA

Average Daily Sleep
Males and females averaged 6.37 hours and 5.94 hours of sleep per day, respectively. This 25.8-minute difference was not statistically significant ($p = 0.81$).

Average Sleep by Duty Station
Differences occurred in average daily sleep as a function of topside and belowdecks working conditions. Individuals working belowdecks averaged 7.35 hours of sleep while those working topside averaged a remarkably low 4.72 hours of sleep per day. This difference was statistically significant ($t = 6.19$, $p<.0001$). As seen in FIGURE 2, the maximum average daily sleep for those working topside (6.33 hours) was very close to the first quartile of sleep hours for belowdecks (6.48 hours). This means that 75% of those working belowdecks received more sleep, on average, than any of those working topside.

Average Sleep Episode Duration
The average sleep episode duration was 5.46 hours for males and 5.78 hours for females. This 19.2-minute difference was not statistically significant ($p = 0.63$).

Those working belowdecks averaged 6.83 hours of sleep per sleep episode. Conversely, those working topside averaged only 3.29 hours of sleep per episode. This surprisingly large difference (3.54-hours) was statistically significant ($p < .001$). The maximum average daily sleep for those working topside (4.83 hours) was very close to the minimum sleep for those working belowdecks (3.76 hours). The topside worker with the longest average sleep episode duration got only 1.07 hours more sleep than the belowdecks worker with the shortest average sleep episode duration.

COMPARISONS BY GROUP

Data were analyzed by splitting them across two dimensions: self-reported adjustment and working condition (i.e., topside versus belowdecks).

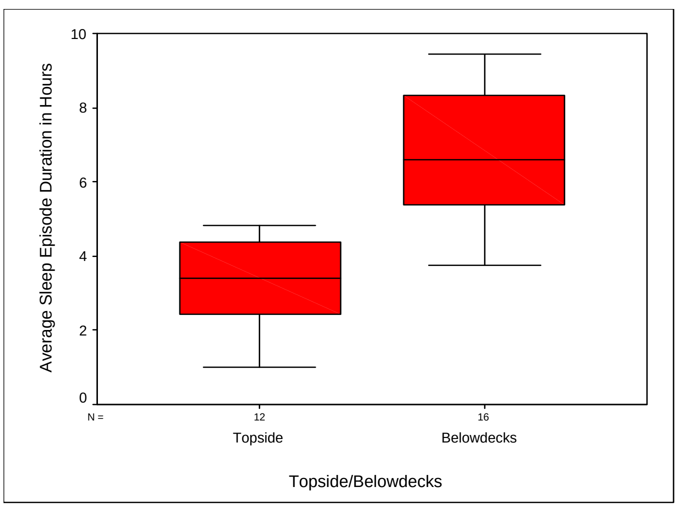

FIGURE 2. Average Daily Sleep by Work Location

FIGURE 3 depicts the relationship between average daily sleep and the total number of sleep episodes, distinguishing topside and belowdecks participants. The graph illustrates that although individuals working topside tended to get more sleep periods than those working belowdecks, their daily sleep averages were much lower than the belowdecks group. Even though they were sleeping more frequently, they tended to receive much less sleep during a 24-hour period $t(22) = 5.31$, $p<.0001$ topside = 4.86 belowdecks = 7.47.

FIGURE 4 depicts the relationship between average daily sleep and the total number of sleep episodes, distinguishing topside and belowdecks participants. Although participants working topside tended to get more sleep periods, the duration of those sleep episodes was shorter resulting in highly disrupted sleep patterns. Those working belowdecks averaged fewer sleep episodes, but they slept longer and had better sleep quality $t(22) = 2.90$, $p<.0008$ topside = 6.17 belowdecks = 4.08.

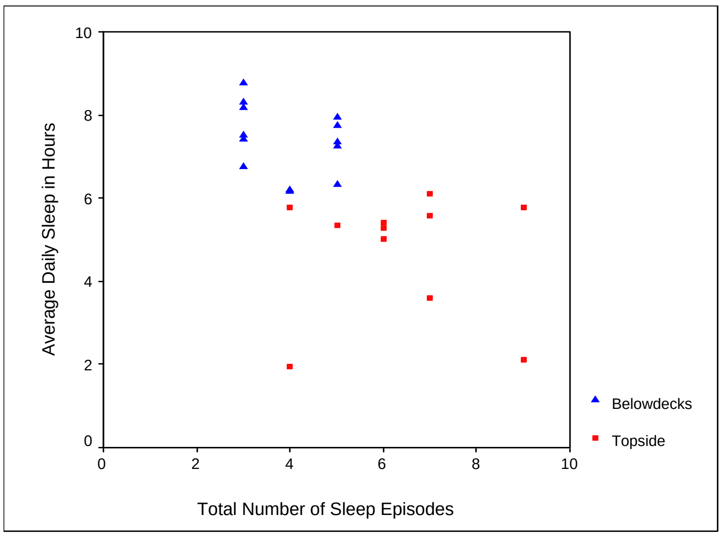

FIGURE 3. Total Number of Sleep Episodes and Average Daily Sleep in Hours by Work Location

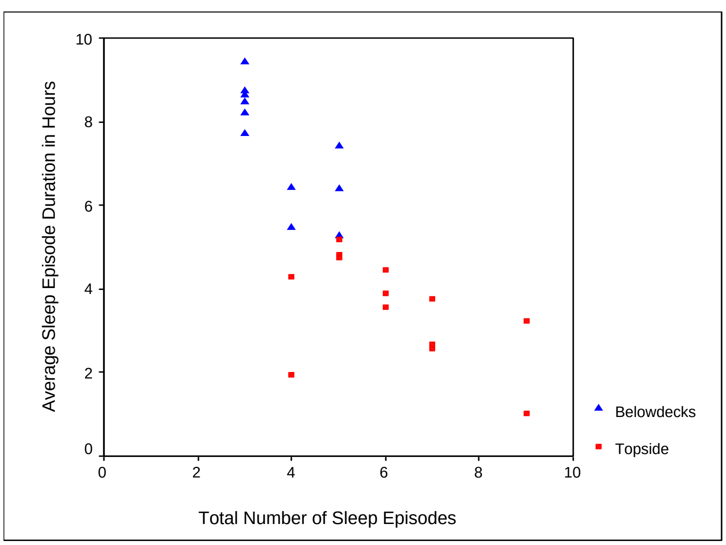

FIGURE 4. Total Number of Sleep Episodes and Average Sleep Episode Duration by Work Location

Using the FAST program, an analysis was performed on the percentage of time participants' predicted effectiveness fell below 78% for topside and belowdecks personnel. The FAST predicted effectiveness level of 78% was chosen based on work done by the U.S. Air Force. This 78% level is used by the U.S. Air Force as the minimal level of predicted effectiveness for their aircrew members during all segments of a given flight profile. Those working belowdecks spent, on average, 35% of their time in the danger area (i.e., below 78% predicted effectiveness). Conversely, those working topside spent a remarkably high percentage (66%) in the danger area. This difference is statistically significant $t(22) = 4.46$. $p<.0001$. FIGURES 5 and 6 illustrate the distribution for these groups in terms of average sleep episode and average daily sleep.

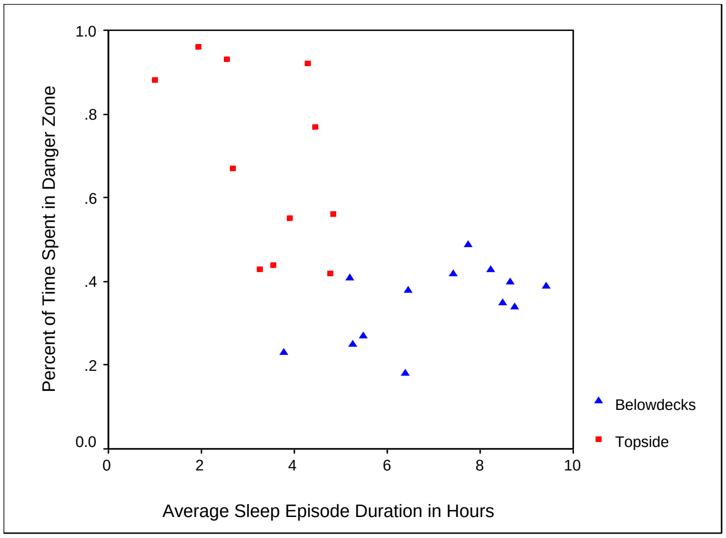

FIGURE 5. Time Spent in Danger Zone and Average Sleep Duration by Work Location

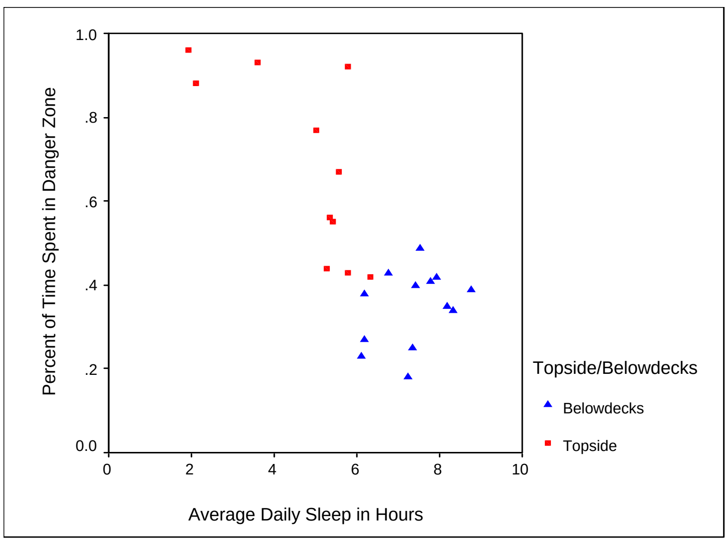

FIGURE 6. Time Spent in Danger Zone and Average Daily Sleep by Work Location

DISCUSSION

This study examined whether fatigue and sleep patterns of crewmembers aboard the *USS John C. Stennis* were affected by reversing the work/rest cycles. The results presented here indicate that reversing the sleep-wake cycle had a profoundly negative effect on the sleep patterns and the reported fatigue levels of the sailors in this study. A large number of the participants in this study reported that they had not adjusted to this reversed schedule, even after 30 days.

There were differences in the quality and quantity of sleep between those working topside compared to those working belowdecks. Working topside dramatically lowered both the amount of sleep individuals received on a daily basis and the average length of their sleep episodes. It is well known that contiguous sleep is superior to fragmented sleep. The nature of the sleep seen in the sailors working topside is clearly inferior to the sleep of their counterparts working belowdecks due to the fragmented nature of their sleep.

Additional analyses using the FAST program showed that the predicted cognitive effectiveness of individuals working topside was clearly degraded. This finding, while preliminary, could have important implications for managing risk of flight deck operations.

Because many sailors and Marines are working on these reversed schedules, the present findings suggest that there is an urgent need to improve how we address the issues of sleep and fatigue for Naval personnel.

The substantial difference in the quantity and quality of sleep for individuals working topside was a surprising finding and may be a major cause for concern. It is evident that sleep deprivation and fatigue due to the reversed schedule was a major problem for many of the participants in this study. We hope that these findings will serve as a catalyst to examine these issues further.

Other factors may have contributed to the differences observed in sleep hours and predicted effectiveness, (e.g., working conditions, light exposure levels, type of work performed, health issues, and combat stress). The sample used in this study was composed entirely of enlisted sailors. Anecdotal data indicate that officers, especially senior officers, may experience similar or even more severe sleep disruptions.

RECOMMENDATIONS

A more detailed study (including baseline data on participants and/or a control group) is needed to explain the substantial differences in sleep between individuals working topside and belowdecks. These data should be collected during work-ups, deployment and recovery periods on the same individuals.

Participants need to be selected to provide an adequate assessment of work conditions, watchstanding schedules, light exposure, type of work, and gender differences. In addition to actigraphy and detailed activity logs, salivary melatonin levels need to be collected to determine the influence of ambient light on sleep patterns. Standardized measures of human performance need to be collected to document any performance decrements that may be attributed to inadequate sleep.

Educating military commanders on the consequences of sleep deprivation and ways to combat sleep debt in order to optimize performance is a major step in addressing fatigue and sleep related problems.

REFERENCES

Colquhoun, W.P. (1982). “Biological Rhythms and Performance,” in <u>Biological Rhythms, Sleep, and Performance</u>, ed. W.B. Webb, New York: John Wiley and sons, 1982, pp. 59-76.

Coren, S. (1996). Sleep Thieves, An Eye-Opening Exploration into the Science and Mysteries of Sleep.

Costa, G. (1996). "Effects on Health and Well-Being", In: Colquhoun, W.P., Costa, G., Folkard, S., and Knauth, P. Shiftwork Problems and Solutions, Peter Lang.

Gillooly, P., Smolensky, M., Albright, D., Hsi, B., and Thorne, D. (1990). "Circadian Variation in Human Performance Evaluated by the Walter Reed Performance Assessment Battery," Chronobiology International, Vol. 2, No. 2, pp. 144-153.

Goh, V.H., Tong, T.Y., Low, E.C., and Lee, L.K. (2001). "Effects of one night of sleep deprivation on hormone profiles and performance efficiency," Military Medicine, Vol. 166, No. 5, pp. 427-434.

Griffith, R. (1993). "Sleep Problems in the Shiftworker," Current Therapies, February, pp. 41-48.

Harrison, Y. and Horne, J.A. (2000). "The Impact of Sleep Deprivation on Decision Making: A Review." Journal of Experimental Psychology, Vol. 6, No. 3, pp. 236-249.

Krueger, G.P. (1989). "Sustained Work, Fatigue, Sleep Loss and Performance: A Review of the Issues," Work and Stress, Vol. 3, No. 2, pp. 129-141.

Mitler, M.M., Carskadon, M.A., Czeisler, C.A., Dement, W.C., Dinges, D.F., and Graeber, R.C. (1988). Catastrophes, sleep, and public policy: consensus report, Sleep, Vol. 11, No. 1, pp. 100-9.

Monk, T.H. (1989) "Shiftwork," In: Kryger, M.H., Roth, T., and Dement, W.C. (1989). Principles and Practice of Sleep Medicine, W.B. Saunders, Philadelphia.

ACKNOWLEDGMENTS

The authors would like to acknowledge the contributions of the following individuals and organizations:

Naval Submarine Medical Research Laboratory (NSMRL), Lt. Jeff Dyche

Walter Reed Army Institute of Research (WRAIR), Col. Dan Redmond and Col. Greg Belenky

USAF AFRL Fatigue Countermeasures Group, Dr. James C. Miller

SAIC, Dr. Steve Hursh

Activity Research, Dr. Tim Elsmore

Naval Postgraduate School, Dr. Jeffrey Crowson , Dr. Michael E. McCauley

United States Military Academy, Col. Lawrence Shattuck

Dr. Nita Lewis Miller, the principal author, serves on the faculty of the Naval Postgraduate School in Monterey, California. Dr. Miller has joint faculty appointments in the Operations Research and Systems Engineering Departments where she teaches human factors engineering, directs the Human Systems Integration Masters degree program, and pursues her research interests in fatigue and human performance. Dr. Miller was a postdoctoral fellow at the USAF School of Aerospace Medicine. She received her Ph.D. in Behavioral Sciences from the University of Texas, School of Public Health.

Lt. John Nguyen is a 2002 graduate of the Naval Postgraduate School in Monterey, California and holds a Masters degree in Operations Research. Lt. Nguyen is a Surface Warfare Officer and is currently attending Department Head School in Newport, Rhode Island.