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Evaluating the Effectiveness of Schedule Changes for Air Traffic Service (ATS) Providers: Controller Alertness and Fatigue Monitoring Study

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Technical Report

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16. Abstract

The FAA's Fatigue Risk Management Program is developing a Fatigue Risk Management System that will include science-based shift scheduling and other strategies designed to maintain air traffic controllers' alertness over the 24-hour clock and to reduce negative impacts of fatigue on Air Traffic Control (ATC) operations. NASA was tasked with conducting research to provide up-to-date knowledge about the state of controller shift work, sleep, alertness and factors contributing to controller fatigue. To that end, the NASA research team conducted a two-pronged effort: a web-based survey of fatigue factors that was available to the entire ATC workforce and a field study that obtained objective measures of sleep, fatigue and alertness in a sample of controllers from selected facilities, including En Route Centers, TRACONs, and ATC Towers. During 2010, 3,268 United States ATC personnel completed the online fatigue survey. The field study resulted in complete data being obtained from 211 controllers working at 30 facilities across the country. Data consisted of 14 days of continuous sleep and activity monitoring using wrist-worn actigraphs, daily sleep and activity logs, a brief objective measure of alertness, and subjective ratings of sleepiness and workload. The purpose of the present study was to establish a quantified baseline for evaluating the impact of the FAA's planned fatigue risk mitigation strategies. Findings also will identify factors affecting fatigue and assist in targeting and designing future research areas. Results from this study were compared to those obtained from a 1999 survey (Della Rocco et al., 2000a) and several field studies conducted by the FAA between 1995-2005 (Della Rocco & Cruz, 1995; Cruz & Della Rocco, 1995b; Della Rocco & Cruz, 1996; Della Rocco et al., 2000b; Cruz et al., 2002; Della Rocco & Nesthus, 2005; Broach & Schroeder, 2005).

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PREFACE

The NASA research team consisted of two coordinated and interleaved work teams that each had primary responsibility for one component of the project. Dr. Bonny Parke led the Fatigue Factors Survey team, which included Dr. Alan Hobbs, Lori McDonnell, and Vicki Dulchinos. Dr. Parke's team designed, conducted, analyzed, and wrote the survey report. The CAFM Field Study team was led by Dr. Norbert Kraft, and included Barrett Anderson and Lori McDonnell. Dr. Kraft's team designed the field study, trained participants at various field locations, managed collection of the objective field study data, and contributed to the final report. Our statistical expert, Dr. Yuri Tada, conducted the analyses of the field study data and contributed to writing the Results section of the field study report.

FAA FOREWORD

The Federal Aviation Administration (FAA) has long considered the operational impacts of human fatigue on Air Traffic Control (ATC) performance and safety. In October 2009, the FAA's Air Traffic Organization (ATO) established the Fatigue Risk Management Team (FRMT), formally committing resources to the topic of fatigue risk and the managed improvement of operational fatigue safety. In July 2011, the FAA and the National Air Traffic Controllers Association (NATCA) signed a Memorandum of Understanding that contained agreements on a set of fatigue related mitigations, which are on track for completion. In June 2012, the FAA implemented an ATO Fatigue Risk Management System (FRMS), with Agency and union membership on the Fatigue Safety Steering Committee. The FRMS will institutionalize the goal of effective management of operational fatigue risk, executed in alignment with FAA's Safety Management System (SMS) principles.

The NASA Controller Alertness and Fatigue Monitoring Study (CAFMS) was sponsored and monitored by the FRMT, which partnered with NATCA to assist with the design, planning and execution of this comprehensive ATC research. The FAA Human Factors Division provided funding and management for the project. The results of this study will establish a body of objective data from which to identify fatigue hazard areas and identify future research areas.

The ATO has recognized that the complex challenges of human fatigue cannot be solved with a single remedy. Thus, the ATO is addressing this important safety issue in the ATC workforce with a comprehensive, multi-layered approach to fatigue risk mitigation. The elements of this approach include:

- Establishing a scientific understanding of the operational fatigue landscape through:
    - a comprehensive fatigue research agenda,
    - data collection, fusion and analysis, and
    - fatigue modeling, all focusing on the fatigue challenges in the ATC shiftwork environment.
- Providing fatigue education, training and promotion within a broad fatigue safety awareness campaign that informs new hires, controllers, managers and all elements of the FAA that influence ATC operational fatigue.
- Collaborating with FAA Aerospace Medicine on sleep disorders, with specific attention to obstructive sleep apnea.
- Providing science-based recommendations within the joint FRMS to improve fatigue safety through policy evolution.

NASA Ames has provided an independent source of data, which will potentially assist the FAA and NATCA in implementing risk mitigation initiatives and which will identify the need for further research and data collection.

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EXECUTIVE SUMMARY

The FAA's Fatigue Risk Management Program is developing a Fatigue Risk Management System (FRMS) that will include science-based shift scheduling and other strategies designed to maintain air traffic controllers' alertness over the 24-hour clock and to reduce negative impacts of fatigue on Air Traffic Control (ATC) operations. NASA was tasked with conducting research to provide up-to-date knowledge about the state of controller shift work, sleep, alertness and factors contributing to controller fatigue. To that end, the NASA research team conducted a two-pronged effort: a web-based survey of fatigue factors that was available to the entire ATC workforce and a field study that obtained objective measures of sleep, fatigue and alertness in a sample of controllers from selected facilities, including En Route Centers, TRACONs, and Air Traffic Control Towers. The purpose of the present study was to establish a quantified baseline for evaluating the impact of the FAA's planned fatigue risk mitigation strategies. Findings also will identify factors affecting fatigue and assist in targeting and designing future research areas. Results from this study were compared to those obtained from a 1999 survey (Della Rocco et al., 2000a) and several field studies conducted by the FAA between 1995-2005 (Della Rocco & Cruz, 1995; Cruz & Della Rocco, 1995b; Della Rocco & Cruz, 1996; Della Rocco et al., 2000b; Cruz et al., 2002; Della Rocco & Nesthus, 2005; Broach & Schroeder, 2005).

Fatigue Factors Survey

During 2010, 3,268 United States ATC personnel completed the online "NASA ATC Fatigue Factors Survey." The survey gathered information on factors that could contribute to workplace fatigue, such as shift schedules, sleep patterns, and workplace experiences. The survey contained statements that were typically rated on a scale of 1 to 5, as well as questions that called for free text responses. Among the various personnel completing the survey, the response rate of Certified Professional Controllers (CPCs) was 18.9% of the CPC population.

The current sample was found to be significantly[1] more fatigued than the comparable sample of controllers in the 1999 survey (Della Rocco et al., 2000a). The current ATC personnel sample was significantly more fatigued on the Chronic Fatigue Scale than a normative comparison group of nurses and industrial shift workers (Barton et al., 1995). Overall 18% of current respondents reported that they had an operational event in the last year with 56% of those who had an operational event self-identifying fatigue as a contributor to the event.

When asked if they had caught themselves "about to 'doze off'" during work duties in the last year, 61% of all respondents and 70% of those with regularly scheduled midnight shifts replied "Yes." CPC respondents also indicated that "fatigue affects the ability of air traffic controllers to perform their job effectively" at an average of 3.7 on a 5 point scale – closer to "Frequently" than "Sometimes."

Schedule Factors

Of all aspects of their jobs included in the survey, respondents were least satisfied with their schedules and felt that their schedules contributed most to their fatigue. Respondents from the current survey had a higher proportion of counter-clockwise rapidly rotating schedules, especially with midnight shifts, and a lower proportion of straight shifts without midnights than the 1999 survey sample. Although over half (54%) of all respondents in this sample did not regularly work midnight shifts, those who did regularly work the midnight shift scored significantly higher on the Modified Brief Fatigue Inventory, Chronic Fatigue Scale, and the Epworth Sleepiness Scale in comparison to those who do not regularly work the midnight shift.

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[1] All results deemed significant were determined utilizing statistical tests, which are documented in the Results section of the report.

Quick turns. About half (51.8%) of the survey respondents described their regular schedules as having a quick turn (8 or 9 hours between shifts) before a morning or midnight shift. The average duration of sleep before morning shifts during these quick turns was reported as 5.4 hours. This reported sleep duration was consistent with an earlier objective field study, an earlier lab study, and the current field study.

On quick turns before midnight shifts that began the same day, controllers reported 3.1 hours of sleep. When respondents' self-reported ratings of mental sharpness at the end of the shift, the midnight shift following a quick-turn ranked as the lowest among all shift types. For midnight shifts following quick turns, respondents also indicated that they felt least rested at the beginning of their shift and more likely during their shift to catch themselves "about to 'doze off'" during work duties when compared to all shift types.

Six-day work weeks. The schedule that respondents were least satisfied with was the 6-day schedule. Respondents working this schedule reported having had a higher proportion of operational events in the previous year than those on any other schedule (32% versus 17%). Although the number of respondents that reported having a 6-day constant bid schedule was small (about 4% of the sample), the proportion of respondents in this sample who reported they actually worked a 6-day schedule in their last full week of work was approximately 14%.

Those who reported actually working 6-day schedules were not evenly distributed across facilities. Over 30% (138/452) of TRACON respondents in this sample reported working a 6-day schedule in the last full week they worked. This compares with 11% of En Route controllers and 12% of Tower controllers working 6-day schedules. Of the TRACON respondents who worked a 6-day schedule, approximately two thirds also reported working midnight shifts. Of those in all facilities who reported working 6-day schedules in the previous week, over half (53%) also reported working midnight shifts.

Field Study of Controller Shift Schedules, Sleep and Alertness

The field study was designed to validate findings from the survey by providing objective measures to complement the self-reports in the survey. Complete data were obtained from 211 controllers working at 30 facilities across the country. Data consisted of 14 days of continuous sleep and activity monitoring using wrist-worn actigraphs, daily sleep and activity logs, a brief objective measure of alertness (the 5-minute Psychomotor Vigilance Task, or PVT) administered three times during each work shift, and subjective ratings of sleepiness and workload.

Controller Work Schedules

Almost three-quarters of participants (72.8%) in the field study worked counter-clockwise rapidly rotating schedules with or without midnight shifts. 61.4% of participants worked a rapidly rotating schedule that included midnight shifts (RRM), a higher level than reported in the survey. This greater representation of RRM schedules most likely reflects the participant recruitment strategy that sought controllers working midnight shifts. The most common RRM schedule (37%) was the 2-2-1 (AAEEM, or two afternoons, two early mornings and one midnight shift, with quick turns before the first morning shift and the midnight shift). Almost as frequent (35%) was a variant that substituted a mid-day shift on day two in place of the afternoon shift (ABEEM). Ninety percent (38/42) of RR schedules with no midnight shifts were characterized as a 2-x-2 (two afternoon shifts, a variable non-midnight shift, and two early morning shifts). At most, these schedules had one turn of less than 12 hours.

Over 21% of field study participants worked one or more 6-day schedules during the study period, a slightly higher rate than the 14% reported in the survey. Like the 5-day schedules, 73.4% of these 6-day schedules were counter-clockwise rapidly rotating schedules with or without midnight shifts; 28% were recognizable as regular 5-day schedules plus one overtime day, either at the beginning or at the end of the week. Of both 5-day and 6-day schedules, 17.5% were interrupted meaning that a day off occurred within a regular work week.

Shift Effects on Controller Sleep

Based on actigraphy and sleep logs, controllers obtained an average of 5.8 hours of sleep per night over the work week, a level similar to that found in prior field studies of controllers (e.g., Cruz & Della Rocco, 1995). The amount of sleep obtained prior to any particular shift reflected the start time of the upcoming shift, regardless of when that shift occurred within a weekly work schedule. The most sleep was obtained prior to afternoon or mid-day shifts: 6.94 and 6.41 hours, respectively. Statistically significant less sleep was obtained before early morning (5.4 hours) and midnight shifts (3.25 hours). The average wake-up time for a shift start time between 05:30 and 08:00 was 04:20. The restricted sleep prior to the midnight shift typically occurred in the afternoon, during a quick turn of 8-9 hours.

Actigraphy data indicated that average total sleep time over a week was greater when participants worked an RR schedule without midnight shifts than when a midnight shift was included. For both schedule types, sleep duration statistically significantly declined across days of the work week.

Participants working 2-2-1 schedules adopted a sleep pattern not evident in prior studies. These participants went to bed earlier prior to early morning shifts as well as arising earlier. In a previous FAA Civil Aerospace Medical Institute (CAMI) field study, controllers working the 2-2-1 schedule did not adjust the time at which they went to sleep, but did adjust their wake-up times (Cruz & Della Rocco, 1995a).

Schedule Effects on Controller Alertness

The 5-minute PVT assessment of alertness was sensitive to changes in fatigue. Both response speed and lapses reflected cumulative fatigue from the beginning of a shift to the end, regardless of shift type, confirming findings from earlier CAMI studies and from the NASA survey.

Alertness also varied with shift start times, regardless of where the shift fell within the work week. Responses were slowest and lapses most frequent during midnight shifts compared to day or afternoon shifts. Responses were also significantly slower during early morning shifts, though lapses did not differ from those in later shifts.

Both increasing lapses and slowing response speeds were measured across the work week. This pattern paralleled the reduction in sleep across the work week, with a significant correlation between amount of sleep and alertness measures. As sleep duration decreased, lapses increased and responses became slower.

Turns. Survey data suggested that quick turns prior to early and midnight shifts significantly contributed to fatigue. Field study results indirectly confirmed these findings. Individual facility-level models showed significant relationships between duration of time off and both response speed and lapses. An analysis of turns ranging from 8 hours to 12 hours prior to early morning shifts found no differences in amount of sleep or alertness between 8 hours and 9 hours off. However, significantly more sleep was obtained when time off increased from 9 to 10 hours and longer, e.g., more sleep was obtained with 13 to 15 hours off than with 8 to 12 hours off. This increase only held when the turn of less than 12 hours occurred before early shifts on day 4, not on day 3, suggesting an interaction between day of work week and time off, i.e., longer time off appeared to have a greater benefit later in the week. Alertness measured by PVT response speed was significantly lower during early shifts following turns of less than 12 hours than following regular hours off (i.e., 13 to 18 hours off).

Workload and alertness. Alertness may also be influenced by workplace factors, such as workload. Although no objective measure of workload during shifts was available in the present field study, subjective perceived workload ratings were significantly related to measured alertness: When workload was rated higher, PVT lapses were fewer and responses were faster. This finding held across shift types and times of day.

Facility Factors as Moderators of Sleep and Alertness

Utilizing data from the field study, multilevel models of fatigue were developed to examine the impact of various factors on sleep and alertness. Facility factors including facility type (En Route, TRACON, Tower), traffic levels, staffing levels relative to FAA target levels, and Certified Professional Controller (CPC) /Developmental ratios were entered into the models to determine their impact on sleep and alertness. No main or moderator effects were found, except for one: Controllers in TRACONS had a longer average sleep duration than those in other facilities.

Demographic Factors as Moderators of Sleep and Alertness

When examining demographic factors, only one main effect of age was found: Older and more experienced controllers responded faster than younger ones, an effect detected when age and experience levels were tested as moderators of the within-shift fatigue effect (i.e., from beginning to end of a shift). This finding contrasts with the negative effect of age found in several prior FAA field studies (e.g., Nesthus, Dattell, & Holcomb, 2005), which found that older controllers generally performed less well than younger controllers on cognitive tasks, especially those involving speed and working memory.

Age and experience moderated the cumulative fatigue effects across the week. In contrast to prior to FAA fatigue research, older controllers showed less decrement in alertness over the week than younger ones. It is unclear whether the differences in age effects between the present study and prior FAA CAMI field studies were due to the tasks used to measure alertness (PVT vs. COGSCREEN), to the schedules worked by participants in the two studies, to actual changes in the controller population across the intervening decade, or to other unknown factors.

Several policy-relevant issues identified by the 2010 survey were not fully addressed by the field study, either because sufficient data were not available for the comparisons or because the survey findings were not expected and only emerged after initial field study analysis plan was completed. Most important of these were (a) the multiple contributions to fatigue on the midnight shift restricted sleep not only during the day prior to the midnight shifts but also in the two prior days, and day of the work week; (b) measured effects of working six day weeks, especially with one or more midnight shifts, and (c) interactions between turns of less than 12 hours and days of the work week on sleep and alertness.

Summary and Conclusions

Findings from the both the survey and field study largely confirmed the major patterns of sleep, fatigue and alertness associated with shift schedules found in prior CAMI studies (summarized in Della Rocco & Nesthus, 2005). There were a few notable differences and additions: The present study found (a) higher levels of reported fatigue and indicators of fatigue including operational events, (b) a greater percentage of survey respondents reported working counter-clockwise rapidly rotating schedules (with or without midnights), and (c) significant fatigue associated with the 6-day schedules which were not included in the 1999 survey.

Several issues emerged from the both the survey and field study for future consideration.

1. Fatigue countermeasures for the midnight shift are necessary to maintain controller performance. Sample research topics related to controller performance on the midnight shift may include instituting a later start time for the early shift prior to the midnight shift, which could enable controllers to accumulate sleep reserve to better cope with the midnight shift.
2. Field study findings and other sleep research indicates that increasing the minimum numbers of hours off (currently 9) between afternoon and morning shifts would allow for longer recovery sleep opportunities and potentially improve controller alertness.
3. Investigate the circumstances requiring 6-day work schedules and ways to reduce the frequency of 6-day work schedules (i.e., those with mandatory overtime).
4. Identify ways to alleviate challenges associated with both scheduling and staffing at TRACONs, and assess and manage workload and overtime hours of Front Line Managers at all facilities.
5. Develop guidelines that assist FLMs in determining how many controllers need to be on position for various traffic levels.
6. Investigate and monitor issues related to fatigue safety culture, such as willingness to request and give breaks or rotations due to fatigue.

7. Approximately 8% of ATC respondents in this sample reported fatigue associated with sleep disorders. The FAA should encourage affected controllers to seek diagnosis and treatment of sleep disorders.

Potential areas for further consideration are included at the end of this report.

1. INTRODUCTION

Air traffic controllers are among the 15% of the US workforce who are considered ‘shift workers’ (Barger, Lockley, Rajaratnam, & Landrigan, 2009). Their schedules involve working outside of normal daylight hours, considered to be from about 7 a.m. to 6 p.m. (NIOSH, 1997). Shifts may change within or across weeks, and often rotate around a 24-hour clock. Shiftwork frequently requires workers to be alert and to function at high levels during hours when they are biologically predisposed to be asleep. Additionally, fatigue may be exacerbated when workers have difficulty sleeping during daytime hours, when their circadian rhythms are normally set to be alert and awake.

Many shiftwork domains involve high-risk operations, including the military, police, fire fighting, medical care, nuclear power, deep-water operations, transportation, space, and some industrial processing. Several accidents with significant consequences have been linked to fatigue among the personnel involved, such as Three Mile Island and the NASA Challenger launch. Society is becoming more aware of the risks associated with fatigue. In part spurred by research supported by the National Institute for Occupational Safety and Health (NIOSH), the medical field is taking steps to limit the number of continuous hours that can be worked by interns (now 30 hours) (Blum, Shea, Czeisler, Landrigan & Leape, 2011). This step was prompted by the significant number of medical errors committed by drowsy personnel, and also because of the high rate of accidents or near accidents while driving home after a long shift.

The National Highway Traffic Safety Administration claims that 100,000 crashes a year are due to driver fatigue (NHTSA, 2000). Fatigue also affects the health and well-being of shift-workers, manifesting in increased incidence of diabetes, gastrointestinal, cardiovascular or pain problems (Caruso, Hitchcock, Dick, Russo & Schmit, 2004). However, our modern 24-hour society requires that important services be provided around the clock. A global economy and production processes that operate longer than a nominal 8-hour work day demand multiple shifts, including during hours when people normally sleep. How to satisfy these productivity and performance demands while maintaining the health and well-being of shift workers is a challenge of modern times.

The role of fatigue in Air Traffic Control (ATC) has long been of concern to the Federal Aviation Administration (FAA) (Melton, et al., 1973; Melton et al., 1975). All En Route facilities operate 24 hours per day, 7 days per week. Over half of federally operated Terminal facilities operate 24 hours per day, 7 days per week (GAO, 2008). In 2007 approximately 60% of controllers worked rapidly rotating 8-hour shifts with progressively earlier start times across the week (GAO, 2008). Controller fatigue has been implicated in several accidents and incidents, notably the Comair 5191 accident in Lexington, KY at 06:06 as the only controller in the Tower was about to complete his midnight shift (NTSB, 2007a). Several runway incursions involved controllers working quick turnaround shifts with 9 hours or less off between shifts (Price, 2008). According to a fatigue factors survey conducted by CAMI, 5-6% of respondents reported they had been involved in an operational deviation or error in the prior year (Della Rocco & Nesthus, 2000); almost half of these felt that fatigue was a factor in their events.

As a result of these and other findings, the National Transportation Safety Board (NTSB) recommended that the FAA and the NATCA work together “to reduce the potential for controller fatigue by revising controller work-scheduling policies and practices to provide rest periods that are long enough for controllers to obtain sufficient restorative sleep and by modifying shift rotations to minimize disrupted sleep patterns, accumulation of sleep debt, and decreased cognitive performance” (NTSB, 2007b). A recent analysis of work and scheduling policies in Chicago area air traffic facilities (ZAU, C90 and ORD) identified additional factors that may contribute to controller fatigue: high traffic volume and complexity, limited position rotation, and a high ratio of trainees to CPCs, which creates higher workload demands on the CPCs, including higher on-the-job training (OJT) demands (DOT OIG, 2009).

The FAA plans to reduce the potential for controller fatigue by implementing a number of fatigue risk management strategies, such as revising work-scheduling policies to ensure sufficient restorative sleep, modifying shift rotations to minimize disrupted sleep and accumulation of sleep debt, and exploring the use of napping and educational programs. Exactly what those changes should be has not been fully determined. Individual differences between controllers in vulnerability to sleep-related fatigue and differences between facilities in traffic volume, staffing levels, or training demands may influence both sleep needs and performance capability, as well as risk mitigation practicality.

The FAA's ATO Safety and Technical Training Fatigue Risk Management Program Office has two requirements that guided the present study. First, the office is tasked with developing a Fatigue Risk Management System (FRMS), a task that depends on an accurate picture of the current state of controller work schedules and factors contributing to controller fatigue, as well as on recent fatigue science. Second, a quantified baseline that reflects the current state of controller sleep, alertness, and fatigue related to current work schedules and policies must be established to enable evaluation of the efficacy of any FRMS that is put into place.

Working under the sponsorship of the FAA's Human Factors Division, the research team at NASA Ames Research Center conducted a study to address the FAA's dual requirements. This study was developed in collaboration with the FAA's ATO Safety and Technical Training, Fatigue Risk Management Program Office and the Article 55 Fatigue Risk Management Work Group on Controller Fatigue, which was a joint effort of the FAA and NATCA. The present study expanded on the 1999 survey by Della Rocco and Nesthus (2000a, 2005) and several field studies (summarized in Della Rocco & Nesthus, 2005) that identified factors disrupting normal sleep and effective cognitive functioning. A new study was deemed necessary due to changes that have occurred during the preceding decade, including changes in ATC and aircraft automation, domestic and international traffic patterns, and controller workforce demographics.

1.1 STUDY PURPOSE

The purpose of the present study was two-fold: (1) to establish a quantified baseline for evaluating the impact of the FAA's FRMS in air traffic operations, and (2) to identify fatigue risk areas, clarify fatigue risk, and assist in targeting and designing specific mitigation strategies.

The FAA ATO Safety and Technical Training Fatigue Risk Management Program, in collaboration with operational service units and unions, will implement a Fatigue Risk Management System (FRMS). The impact of the FRMS will be evaluated following implementation, after sufficient time for the new policies and practices to take hold.

Using similar tools and methods, the present study updates the findings of the earlier research conducted by the FAA's Civil Aerospace Medical Institute (CAMI) (Della Rocco & Nesthus, 2000; 2005) to determine what patterns still hold and what patterns have changed.

1.2 BACKGROUND

A significant amount of literature has accumulated on the nature and sources of fatigue. A parallel body of literature has described shiftwork and its relationship to fatigue and human performance.

1.2.1 Sleep Science, Fatigue and Alertness

Advances in sleep science are important to understanding the impact of shift schedules and fatigue management practices on controller alertness and fatigue. These advances can be broadly grouped into five major topic areas: circadian pacemaker, homeostatic pressure, chronic fatigue, sleep inertia, and napping and recovery sleep (Banks & Dinges, 2007; Barger et al., 2009; Mallis, Mejdal, Nguyen & Dinges, 2004). These are reviewed briefly, as they serve as the foundation for understanding the results of our study and implications for development of an Air Traffic Organization FRMS.

1.2.1.1 Circadian Pacemaker

Normal sleep and wake patterns in healthy adults reflect the interaction between two primary factors: the circadian pacemaker and the homeostatic drive for sleep (Borbe'ly & Achermann, 1999). Circadian factors are endogenous rhythmic patterns that are responsible for fluctuations in wakefulness over the course of a 24-hour period. Entrained by changing light over the day-night cycle, they influence major biological functions, including metabolic, temperature, neuroendocrine and neurotransmitters. Considered our 'internal clock,' the circadian pacemaker is responsible for increased alertness when the sun comes up—or in environments not exposed to sunlight, such as in a submarine, space vehicle, or other artificial environment—and a propensity to sleep after the sun goes down.

Influence of the circadian pacemaker is evident in patterns of alertness over a 24-hour cycle, regardless of the amount of sleep one receives. Major and minor peaks of alertness are seen in the morning around 10:00 and again in the evening around 20:00. Alertness and performance decline to a minimum at around 04:00, with another dip in the early afternoon, around 13:00-14:00 (Hursh, Balkin, Miller & Eddy, 2004; Minors & Waterhouse, 1985).

Even when one is sleep deprived, performance improves during the morning alertness peak. Conversely, it diminishes during the circadian trough at night. Figure 1-1 illustrates the combined effects of circadian rhythms and homeostatic pressure on a test of logical reasoning. The oscillating peaks reflect circadian factors, while the overall decline across time reflects increasing homeostatic pressure to sleep.

The role of the circadian pacemaker is especially evident in the case of circadian dysrhythmia, when one travels to a new time zone and the day-night cycle becomes de-synchronized with respect to one's internal clock. Circadian factors are believed to be responsible for the high incidence of accidents in the early morning hours, at the circadian trough (Dijk, Duffy & Czeisler, 1992), especially if one has been up all night. These also may be implicated in some ATC incidents at that hour as well (NTSB, 2007b; Pruchnicki, Wu & Belenky, 2011).

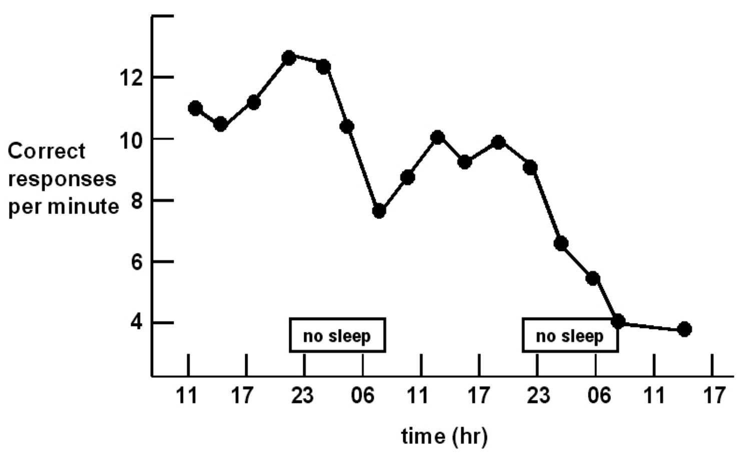

Figure 1-1. Logical reasoning performance across two nights of sleep deprivation. (Angus & Heslegrave, 1985)

1.2.1.2 Homeostatic Pressure

Homeostatic pressure is driven by the number of hours awake. Homeostatic pressure to sleep builds up with increasing hours awake. Studies of the effects of sleep restriction show that neurocognitive performance on tests of alertness, such as the Psychomotor Vigilance Task (PVT), begins to show decrements after 15.84 hours awake (Van Dongen, Maislin, Mulington & Dinges, 2003). Continued lack of sleep results in acute fatigue arising from homeostatic pressure.

The homeostatic pressure combines with circadian processes to determine the timing of sleep resulting in a regular sleep-wake cycle. As one sleeps, the homeostatic drive diminishes in an exponential fashion meaning that there is a steep drop in the drive to sleep at the beginning of the sleep period (Van Dongen, et al., 2003). The rapid satisfaction of homeostatic drive makes naps beneficial. However, even when one is sleep deprived and homeostatic pressure is strong, circadian factors may be in conflict, especially during the day, making sleep difficult.

1.2.1.3 Chronic Fatigue

Chronic fatigue is a function of the amount of sleep obtained on an extended basis and occurs when the amount of sleep obtained over successive days is less than needed, which is usually 7-9 hours in healthy adults. When one obtains less sleep than needed over a period of time, the level of neurocognitive functioning diminishes and may remain stable at a less than optimal level (Belenky et al., 2003). The need for sleep builds over time and a 'sleep debt' accumulates requiring recovery sleep to get back to a full level of functioning (Belenky et al., 2003). Recent evidence suggests strong individual differences in vulnerability to sleep deprivation with respect to neurocognitive functioning (Van Dongen et al., 2004).

1.2.1.4 Sleep Inertia

Immediately upon awakening, individuals may experience grogginess and lower levels than usual of neurocognitive functioning on alertness measures, such as the PVT and other cognitive tests (Barger et al., 2009; Bruck & Pisani, 1999). This inertia gradually dissipates, but may last from 30 minutes to two hours. Sleep inertia is more severe under conditions of sleep deprivation and during the circadian trough at night (Van Dongen & Dinges, 2005).

1.2.1.5 Napping and Recovery Sleep

Overcoming the negative effects of sleep restriction or deprivation can be accomplished by sleeping, either as naps (brief sleep periods up to two hours at any time of day) or as recovery sleep (longer sleep, usually during the circadian night) (Van Dongen et al., 2003). Naps have been demonstrated to release homeostatic pressure resulting in increased alertness and improved neurocognitive functioning (Della Rocco et al., 2000). In one study individuals were kept awake 24 hours a day, but permitted 2-hour naps every 12 hours. These naps served to maintain high levels of cognitive functioning, apart from sleep inertia effects observed immediately upon awakening (Banks et al., 2010; Purnell, Feyer, & Herbison, 2002).

The benefit of recovery sleep depends on the nature and extent of prior sleep restriction, as well as the recovery sleep dose. The largest impact of recovery sleep is seen in cases of complete sleep deprivation compared to partial sleep restriction. For example, recovery sleep almost completely eliminated the effect of 14 days of sleep deprivation but only partially reduced the effect of sleep restricted to 6 hours per night (Van Dongen & Dinges, 2005). Recovery sleep was more effective when sleep was restricted to 4 hours than to 6 hours. Even with 10 hours of time in bed following five nights of 4 hour sleep restriction, neurocognitive functioning had not fully recovered to the baseline level suggesting that even longer sleep or multiple nights of recovery sleep would be needed.

The FAA has supported over 40 years of research that addresses fatigue within air traffic control. This literature will be reviewed briefly, following a brief description of the actual schedules worked by U.S. air traffic controllers.

1.2.2 ATC Shift Schedules

Shift schedules may be characterized in terms of the following variables. These features are important for analyzing the impact of the schedules on workers' alertness, fatigue and operational performance. Schedules are distinguished by:

- Duration of a shift

• Time at which a shift starts
• Number of shifts worked before a day of rest
• Number of opportunities for night-time sleep during the week
• Number of rest days following a work period (week or other block of contiguous work shifts)
• Amount of overtime and how taken (extra hours added to a shift or an extra shift)
• Amount of time off available between shifts
• Amount of rest taken during the shift
• Whether the work schedule is regular or changes across days

Nominal ATC shift schedules consist of five 8-hour work days followed by two regular days off (RDO). How these schedules are configured varies substantially across ATC facilities depending on local needs. The schedules are composed from the five different shift types listed below in Table 1-1. The most common types of ATC shift schedules are depicted in Table 1-2 below.

Table 1-1. List of Shift Types
(Della Rocco & Nesthus, 2005)

Shift	Shift Start Time
Early morning (E):	Between 01:00 – 07:59
Day (D):	Between 08:00 – 09:59
Mid-Day (B):	Between 10:00 – 12:59
Afternoon (A):	Between 13:00 – 19:59
Midnight (M):	Between 20:00 – 00:59

Table 1-2. 'Typical' 2-2-1 and 2-1-2 Shift Schedules
(from Della Rocco & Nesthus, 2005)

2-2-1 Schedule

Shift	Schedule	Hours between Shifts
1 (A)	15:00–23:00	15
2 (A)	14:00–22:00	9
3 (E)	07:00–15:00	14
4 (E)	06:00–14:00	8
5 (M)	22:00–06:00*	-

2-1-2 Schedule

Shift	Schedule	Hours between Shifts
1 (A)	15:00–23:00	15
2 (A)	14:00–22:00	13
3 (B)	11:00–19:00	12
4 (E)	07:00–15:00	15
5 (E)	06:00–14:00	-

* Shift 5 actually begins at 22:00 on Day 4

Counterclockwise Rapid Rotation with a Midnight Shift (RRM): Rapidly rotating shift schedules change one or more times during a schedule week. In counterclockwise rotations, each successive shift begins earlier than the prior one. A common shift worked by controllers over many years involves two afternoon shifts, followed by two early morning shifts, followed by one midnight shift (commonly called the 2-2-1 schedule). Typical shift times for a 2-2-1 schedule are shown in the left column of Table 1-2. While RRM schedules usually begin with an afternoon shift and end with a midnight shift, the intervening shifts may vary, such as AABEM, ABDEM, and other combinations.

Counterclockwise Rapid Rotation with No Midnight shift (RR): RR schedules are similar to RRM schedule, except that they do not include a midnight shift. An example of a common RR schedule in ATC, the 2-1-2, is shown in the right column of Table 1-2.

Straight 5's or Slow Rotations (SR): This schedule involves working the same shift for five days, then rotating to a different shift on succeeding weeks, thus, a slow rotation. For example, week one may involve five afternoon shifts, week two may involve five mid-day shifts, and week three may involve five early morning shifts.

Straight Shifts: In straight shifts the same shift is worked all week, every week, with no rotation. Shifts can be early, afternoon, midnight or other.

Four-day 10-Hour Shifts: Four-day 10-hour schedules may be straight or rotating; they typically do not include midnight shifts. For example, two 10-hour afternoon shifts may be followed by one 10-hour day shift, one early shift, and then three days off.

In addition to nominal schedules, controllers may also work overtime, either as extra hours on a scheduled day or as extra days. This yields a 6-day schedule with potentially only one day off before the next week's schedule begins.

A general overview of the characteristics of each schedule type is described below.

Counterclockwise Rapid Rotation with a Midnight Shift (RRM): The major advantage of the RRM schedule is a compressed work week, with only one midnight shift during the week. This schedule allows time for recovery sleep following the midnight shift, with approximately 80 hours off between work weeks (from completion of the midnight shift between 06:00 and 08:00 on Day 5, followed by 2 full days off plus a half day before beginning the next work week on an afternoon shift between 13:00 and 18:00).

The main challenge of the RRM schedule, in particular the 2-2-1, is the inclusion of two quick turns between shifts that limit the opportunity for restorative sleep during the work week. Quick and very quick turns have been defined as time off between shifts of 8 to 9 hours. Turns of less than 12 hours were also examined. In a 2-2-1 schedule these quick turns occur between the second afternoon shift and the first early morning shift (typically 9 hours) and between the second early morning shift and the midnight shift (typically 8 hours), as illustrated in the left column of Table 1-2. The 2-2-1 schedule also challenges normal circadian rhythms because of constantly changing shift start and end times, sometimes referred to as 'shift lag' (Comperatore & Krueger, 1990). This circadian challenge is compounded by the fact that it is commonly difficult to sleep during the day before the midnight shift, when humans are biologically conditioned to be alert and awake.

Counterclockwise Rapid Rotation with No Midnight Shift (RR): The major advantage of the RR schedule (e.g., 2-1-2), similar to the 2-2-1, involves a compressed work week resulting in relatively long time off between work weeks. This is a shorter time off between work weeks than the 2-2-1. Since there is no midnight shift, this schedule avoids the circadian disruption, stress, and fatigue associated with midnight shifts, in particular the difficulty sleeping during the day prior to the midnight shift. This schedule may be challenging because shift start and end times also change every day or two, thus disrupting circadian rhythms. Time for restorative sleep is limited by the counter-clockwise rotation.

Straight 5s or Slow Rotation: The major advantage of the Straight-5 schedule is that work shifts start and end at the same time over five consecutive days enabling controllers to go to bed and wake up at consistent and predictable times during the work week. This schedule enables a more stable work routine.

However, working an early shift or a midnight shift five days in a row may take a toll in terms of reduced overall sleep during the week, either because people accommodate to the early shift by awakening very early without going to bed sufficiently early or because they have difficulty sleeping during the day when working the midnight shift (Folkard, 2008).

Straight Shifts: The major advantage of the Straight Shift schedule is that it maximizes consistency and predictability of sleep and work hours, and permits circadian adjustment to the permanent schedule, especially when it begins in the morning, day, or afternoon hours.

However, straight night shifts pose a major challenge to most workers. Research shows that most people have difficulty adapting to working a night shift on a permanent basis (Akerstedt, 1988; Melton et al., 1973). For controllers, a further disadvantage is that traffic levels vary at most ATC facilities across hours of the day, with high levels of traffic during certain daylight hours and low levels of traffic during night shifts.

Four-Day, 10-Hour Shifts: Four-day, 10-hour shifts are desirable because they include an extended number of days off after the 4-day work week. The benefits of this schedule may be tempered depending on specifics of the shifts, i.e., straight or rotating. Initial concern that problems associated with other RR schedules may be exacerbated due to the extra two hours per work day. This concern was addressed by research that found equivalent amounts of sleep for RR 10-hour shifts and the first four days of the 2-2-1 schedule (i.e., not counting sleep prior to midnight shifts) (Schroeder, Rosa & Witt, 1998). Similarly, alertness was maintained in the 10-hour schedules.

Six-Day Schedule: While some facilities require one day of planned overtime each week, 6-day schedules are not considered normal schedules. If the sixth day is added to a nominal 5-day schedule without maintaining the two regular days off, additional fatigue may accrue. This may be a result of a longer work week compounded by reduced time off for essential recuperation between weeks. Six-day schedules also may involve multiple midnight shifts, which impose further stress.

1.3 PRIOR FAA FATIGUE RESEARCH

The FAA has supported research on controller fatigue for the past 40 years (e.g., Higgins et al., 1976; Melton et al., 1973; see Della Rocco and Nesthus, 2005, for a summary of earlier research). This body of work involves multiple approaches including surveys, field studies, and laboratory experiments. Studies have addressed the impact of work schedules and other fatigue factors on a number of measures of importance to controller job performance—namely, the amount and quality of sleep, timing of sleep, cognitive performance and alertness, subjective measures of fatigue, alertness, and mood, controller health and safety, and operational events.

Even though some of the CAMI studies go back many years, they are important to consider in relation to the present study. The majority of the earlier work was conducted between ten and twenty years ago and published between 1995 and 2005. Many aspects of the ATC job and worker demographics have changed: ATC technology air traffic volume, routes and complexity, aircraft automation capabilities, air traffic management policies. Despite these changes, the job of controlling traffic has maintained a constant core over the years. Controllers continue to perform a job around the clock in a high-consequence dynamic environment. The FAA initiated the present study to determine whether findings from their prior research still hold or whether fatigue factors have changed due to developments in the world and technologies over the past decades. An up-to-date fatigue baseline is needed for assessing the efficacy of the FAA's planned controller fatigue management strategies.

Several findings from the earlier body of work are relevant because they served as the foundation for design of the present study as well as the basis for interpreting current findings.

Finding #1: Shift start times influence the duration, quality, and timing of sleep during time off periods between shifts. The greatest amounts of total sleep preceded mid-day and afternoon shifts, significantly less sleep preceded early morning shifts (that begin before 07:59), and the least sleep preceded midnight shifts (mean total sleep time = 3.3 hours). Sleep adjustments to the early morning start times were limited to time of awakening, not time going to sleep (Cruz & Della Rocco, 1995).

Finding #2: Alertness is significantly challenged during midnight shifts. In addition to combined circadian and homeostatic pressures, midnight shifts frequently occur at the end of a work week when controllers may also suffer from cumulative fatigue. Controllers may find it difficult to sleep during the afternoon prior to a midnight shift because of the circadian phase—their bodies are set to be alert in the afternoon—and because of personal or family factors (Cruz & Della Rocco, 1995; Della Rocco & Cruz, 1995).

Finding #3: The two schedules with the greatest reported fatigue and lowest alertness are the 2-2-1 and straight early morning schedules. In some cases, the straight early morning schedule was found to be more fatiguing than the 2-2-1. This finding may reflect less total sleep time for those who must get up very early (e.g., 04:30) in time to get to work for a shift that starts at 06:00. The 2-1-2 schedule resulted in the greatest amount of sleep, most positive mood scores, and highest subjective alertness ratings. This schedule permits workers to sleep later in the morning for the first three days of the week and involves no midnight shifts (Cruz & Della Rocco, 1995; Nesthus, Dattell & Holcomb, 2005).

Finding #4. Longer periods of time off between shifts are associated with increased alertness. A comparison of numbers of hours off in a 2-2-1 schedule during the quick turn from the second afternoon shift to the first early morning shift found that subjective alertness increased significantly from 9 hours off compared to 8 hours off (Cruz & Della Rocco, 1995). However, no further improvement was associated with 10 hours of time off, although the sample size with 10 hours off may have been too small to be reliable. Other comparisons found greater alertness when hours off were greater than 12 hours (compared to 8-11 hours off) (Nesthus, et al., 2003).

Finding #5. In contrast to finding #4, a laboratory study that compared clockwise and counter-clockwise rapidly rotating schedules found no significant difference in amount of sleep obtained across the work week, nor did the groups differ in measured alertness based on the Multiple Task Performance Battery. In both schedules the expected differences in sleep duration associated with shift start times were observed, e.g. the lowest total sleep times prior to early morning and midnight shifts, the greatest total sleep time prior to afternoon shifts (Cruz, Boquet, Detwiler & Nesthus, 2003; Cruz, Detwiler, Nesthus & Bouquet, 2003). Clockwise rotating schedules, i.e., EEAAM, were expected to lead to longer sleep and greater alertness due to eliminating both quick turns associated with the counter-clockwise 2-2-1 schedule, but this was not found.

Finding #6. Both subjective alertness and measured performance deteriorate across the work day. The magnitude of this decrement is greatest on a midnight shift, which may begin during a circadian high at 20:00 and may end between 04:00 and 09:00, typically a circadian low period (Becker, Nesthus, Caldararro & Luther, 2006; Nesthus, et al., 2005).

Finding #7. Fatigue accumulates across consecutive days of the work week, reflected in self-report sleepiness ratings and measured performance. In counter-clockwise rapidly rotating schedules, shifts later in the week are typically early morning or midnight shifts, both of which are associated with more fatigue than daytime shifts. These shifts involve work during circadian lows. In addition, by the end of a work week sleep debt accumulates as a result of a compressed week and one or more quick turns that limit opportunity for restorative sleep (Cruz & Della Rocco, 1995; Schroeder, Rosa, &Witt, 1998).

Finding #8. Based on a laboratory study, the total amount of sleep and alertness associated with 10-hour 4-day shift schedules did not differ significantly from the first four days of a 5-day 8-hour 2-2-1 shift schedule when matched for shift types (Schroeder, et al., 1998).

Finding #9. Age was a factor in controllers' responses to various shift schedules, primarily by increasing vulnerability to the effects of quick turns (Becker, et al., 2006; Della Rocco & Cruz, 1996). Controllers greater than 40 years of age also performed less well on tasks associated with higher speed and greater working memory. However, when older controllers rated their mental alertness as high, their performance also was higher.

1.4 GENERAL APPROACH OF THIS STUDY

The NASA team conducted a two-part study to address the two FAA requirements. The first part consisted of a survey distributed online to the U.S. controller workforce. The survey borrowed from the earlier survey by Della Rocco and colleagues (Della Rocco, Ramos, McCloy & Burnfield, 2000a) and updated the questions and formats in consultation with the joint FAA and NATCA Article 55 Fatigue Risk Management Work Group. The survey was structured to identify both bid and actual schedules worked in various facility types by controllers with varying levels of certification and experience. Additionally the survey was structured to identify perceived alertness and fatigue and the factors contributing to each. Topics addressed in the survey included: bid and actual shift schedules worked, work and stress-related fatigue factors, sleep duration, sleep quality and patterns, self-reported alertness, observed and self-reported fatigue, strategies for reducing fatigue, and personal demographics. The survey also provided fields for respondents to offer their views on what could be done at varying levels of management and supervision to mitigate fatigue and ensure controller alertness.

The second component of this effort was a field study involving a sample of approximately 250 controllers at targeted facilities (En Route, TRACON, and Towers). Over a 14-day study period, participants provided data on the duration and efficiency of sleep obtained when working various shift schedules along with objectively measured cognitive alertness associated with the schedules and sleep practices. Controller demographics and facility features (e.g., traffic levels, staffing levels, facility type) were examined as moderators of the relationships.

Together, the two sets of data addressed questions concerning the impact of schedules on sleep quantity and quality, perceived fatigue, and perceived and measured alertness. These findings will provide the FAA with more accurate and up-to-date estimates of schedule-related fatigue, and identify factors contributing to fatigue. The hierarchical structure of the data allow for determining whether these effects are consistent across various factors, or vary with the type of facility, levels of traffic or staffing, age or level of controller experience, controller job category, or personal rest practices.

This report is organized in three major sections following this introduction. Section 2 includes the report on the Fatigue Factors Survey. Section 3 contains the report on the Controller Alertness and Fatigue Monitoring (CAFM) field study. An integrated discussion and recommendations from our findings appear in Section 4.

2. NASA ATC Fatigue Factors Survey

2.1 METHODOLOGY

2.1.1 Survey Development

The survey was developed by researchers from the NASA Ames Human Systems Integration Division, with inputs from the FAA, NATCA, and subject matter experts in the fields of air traffic control and fatigue. Topics addressed in the survey included shift schedules, sleep patterns and naps, sleep quality, alertness and fatigue, workload management, job satisfaction, and workplace stress. The survey contained many items from an earlier FAA survey (Della Rocco, et al., 2000). Items retained from the previous study demonstrated sensitivity to schedule differences or provided baselines against which results could be compared. In addition, the current survey contained questions that did not appear in the 1999 survey. These items dealt with such topics as safety culture, workload, stress-related fatigue, and perceived risk of controller fatigue. Respondents also were asked to suggest how controller fatigue could be reduced by supervisors, upper FAA management, and controllers themselves.

The survey consisted of Likert scale ratings (usually from 1 to 5), categorical choice options, and free text questions. Free text fields in which optional comments could be added were at the end of each section. The survey concluded with demographic questions including age, position, years of experience and facility type.

2.1.2 Development and Review of Survey

Once the proposed items were compiled into a draft survey, a panel of Subject Matter Experts (SMEs) consisting of recently retired controllers was enlisted to ensure that wording was clear, that correct terminology was used, and that response options were appropriate. Each SME completed the draft survey, and the time taken to complete the survey was recorded. The SMEs were then debriefed in order to identify items that required modification.

NASA, the FAA, and NATCA jointly reviewed subsequent iterations of the survey to ensure the concerns of all parties were addressed. These reviews were conducted via teleconference and the parties discussed each item on the survey, made recommendations for additions, deletions, modifications, and provided guidance for the study protocol. The FAA and NATCA approved the final version of the survey before distribution to ATC personnel. The survey and the associated research plan received the necessary approval from the NASA Ames Human Research Institutional Review Board (Protocol #HRII-09-10 dated June 30, 2009 and HRII-10-24 dated July 27, 2010). A copy of the survey is provided in Appendix A.

2.1.3 Survey Administration

The survey was administered online. This enabled participants to complete it during their work hours at computer workstations at their facilities. The survey was available online from April 15, 2010 to December 31, 2010.

The FAA sent a letter describing the goals and the scope of the study to all facilities and NATCA field representatives. A poster advertising the survey was also made available. The letter included the following points to promote participation:

1. "Facilities should make one or more computer(s) with internet access available for staff to use to complete the survey."
2. “More than one computer may be required to accommodate the number of staff in your facility that will need to complete the survey during the survey time frame.”

3. “The survey will be available online from April 15th through June 15th, 2010 [subsequently extended to December 31, 2010]. “
4. “The survey should take about 35 minutes to complete.”
5. “The survey can be taken on any designated computer during work hours (duty time).”
6. “Supervisors, Managers and Facility Representatives will need to plan ahead to accommodate the schedule flexibility required to allow staff the time needed to complete the survey.”
7. “Web-based survey responses will go directly to NASA Ames Research Center for analysis.”
8. “All survey responses will be completely anonymous; no personal identifying information will be requested.”
9. “The attached survey poster reflects the information above."

The following personnel were encouraged to take the survey:

- All Controllers, including Developmentals
- Front Line Managers
- Operations Managers
- Supervisor
- Traffic Management Coordinators

Paper surveys were available but were to be used only if the online survey was not easily accessible. A copy of the paper survey was included in the package of information provided to facility managers to print for use, if needed. Managers were asked to provide employees with postage-paid return envelopes to mail the completed surveys directly to NASA. No paper surveys were submitted to NASA resulting in 100% of the received surveys being completed online.

In its introduction on the website, the stated goal of the survey read as follows.

> "This survey will help NATCA and the FAA understand fatigue in the air traffic controller work force. It will gather controller inputs on factors that contribute to workplace fatigue, such as shift schedules, sleep patterns and workplace experiences.
>
> Your input will be analyzed by NASA Ames Research Center and that analysis will be used by the joint NATCA and FAA Fatigue Risk Management Work Group to help develop ways to reduce fatigue risk to the ATC workforce and the NAS."

2.1.4 2010 Schedule Categories

The final 2010 schedule categories were based on current research on fatigue and questions from the respondents on schedules. The data were later put into the 1999 survey categories for purposes of comparison. The 2010 schedule categories were based on their predicted relationship to fatigue as well as in response to the suggestions for schedule changes proposed by respondents in free text sections of the 2010 survey. The two additional schedule types included in the 2010 schedule categories were the 6-day schedule and the 10-hour 4-day schedule.

2.1.5 Fatigue Scales

There were three fatigue scales in the survey—each measuring a different aspect of fatigue. The Modified Brief Fatigue Inventory (MBFI) indicates the extent to which fatigue interferes with recent mood and daily activities. The Chronic Fatigue Scale indicates the extent to which one always feels fatigued, independent of particular sleep events or activities, and was used in both the 1999 survey and

2010 survey. The Epworth Sleepiness Scale measures the propensity to fall asleep, e.g., the extent to which one tends to fall asleep in various situations in recent months.

2.1.5.1 Modified Brief Fatigue Inventory

The Modified Brief Fatigue Inventory indicates the extent to which fatigue interferes in one's daily activities. It was originally designed to assess the level of fatigue in cancer patients (Mendoza, et al., 1999). It has been shortened and modified to apply to fatigue "in recent months," rather than to fatigue occurring currently while taking the test and within the previous 24 hours. It is comprised of the following rating items on a scale of 1–5 from "Not at all" to "Very much," which are then added to give a MBFI score (see Survey Question 63 in Appendix A).

> "Rate the extent to which, in recent months, fatigue has interfered with your:
> 1. activity level
> 2. mood
> 3. work
> 4. home chores
> 5. relationships
> 6. enjoyment of life"

2.1.5.2 Chronic Fatigue Scale

The Chronic Fatigue Scale consists of a series of statements meant to capture chronic fatigue on a scale from 1–5, and as stated earlier, was used in both the 1999 and 2010 survey (see Survey Question 64 in Appendix A). The even-numbered items are reverse coded[2] and added to the odd-numbered items to yield a final score.

> "The following items relate to how tired or energetic you generally feel, irrespective of whether you have had enough sleep or have been working very hard. Some people appear to "suffer" from permanent tiredness, even on rest days and holidays, while others seem to have limitless energy. Please indicate the degree to which the following statements apply to your own normal feelings."
> 1. I generally feel I have plenty of energy.
> 2. I usually feel drained.
> 3. I generally feel quite active.
> 4. I feel tired most of the time.
> 5. I generally feel full of vigor.
> 6. I usually feel rather lethargic.
> 7. I generally feel alert.
> 8. I often feel exhausted.
> 9. I usually feel lively.
> 10. I feel weary much of the time."

2.1.5.3 Epworth Sleepiness Scale

The Epworth Sleepiness Scale (Survey Question #62 in Appendix A) asks the respondents about the likelihood of their dozing during a number of activities and provides four categories of responses: No chance of dozing, slight chance of dozing, moderate chance of dozing, and high chance of dozing. The four rating categories (0–3) were added together to give a final score.

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[2] All items receive a score of 1- 5, but the scores on the even-number items are reversed such that a 5 = 1, 4 = 2, 3 = 3, 4 =2, and 5 = 1.

"How likely are you to doze off or fall asleep in the following non-work situations in recent months, in contrast to just feeling tired?

- Sitting and reading
- Watching TV
- Sitting inactive in a public place (e.g., a theater or a meeting)
- As a passenger in a car for an hour without a break
- Lying down to rest in the afternoon when circumstances permit
- Sitting and talking to someone
- Sitting quietly after a lunch without alcohol
- In a car, while stopped for a few minutes in traffic"

2.1.6 Survey Return

As of December 31, 2010, 3,268 usable surveys had been received. Four surveys were deemed unusable due to insufficient responses (less than half of the survey was completed). The relatively low number of unusable surveys may reflect the convenience of the online delivery method, which returned data only when the respondent chose to click the "finish" button.

2.2 RESULTS

Results are presented in tables when appropriate and graphically when possible. When error bars are used in graphs, they are the 95% Confidence Intervals (CIs) as recommended by the American Psychological Association (APA, 2001, p. 22). These error bars can be used to gauge whether the means are significantly different from each other. If the confidence intervals around two means do not overlap or overlap only slightly, then generally the means are significantly different from each other. Note that:

> "...when sample sizes are similar and not small and CI widths are similar, if 95% CIs on independent means just touch, the two-tailed *p* value is about 0.006, not 0.05 as many believe." (Belia et al., p. 393 citing Cumming & Finch, 2005; Payton et al., 2003).

2.2.1 Demographic Data

2.2.1.1 Types of Facilities and Number of Respondents

About half (50.5%) of the respondents indicated they were from En Route facilities, one third (33.7%) from Towers, and 14.3% from TRACONs, as shown in Table 2-1. As can be seen, nearly all (99.4%) respondents identified the type of facility they were from.

Table 2-1. Number and Proportion of Respondents from Each Facility Type

Facility Type	Number of Respondents	Percent of Total Respondents
En Route	1,650	50.5%
Tower*	1,101	33.7%
TRACON	467	14.3%
Other[3]	29	0.9%
Missing	*21*	*0.6%*
Total	3,268	100.0%

**Includes tower/TRACON combinations*

2.2.1.2 Positions of Respondents and Response Rates

About 86% of all respondents were operational controllers, i.e. either Certified Professional Controllers (CPCs) or Developmentals; the rest were mostly supervisory personnel, as shown in Table 2-2. Response rates are shown where possible. The ratio of CPCs to Developmentals (82.5% to 17.4%) was similar to their ratio in the operational controller population as of December 18, 2010 (80.3% to 19.7%).

Three main categories were distinguished for analysis purposes. Several management, supervisory and support positions were combined into a single category of "Other," as shown in Table 2-2. This yielded three main categories: CPCs, Developmentals, and Front Line Managers (FLMs) who supervise CPCs and Developmentals, as shown in Table 2-3. The overall response rate for those positions for which there is population data is 17.7% (3224/18204).

[3] Most (18) respondents in the "other" category were from the Document Control Center (DCC), a few (8) were from the Air Traffic Control System Command Center (ATCSCC), and several (3) were from FAA Headquarters.

Table 2-2. Proportions of Respondents in Various ATC Positions and Available Response Rates

Current Position	%	#	Total in Population	Response Rate
Certified Professional Controller (CPC)	70.9%	2,316	12,228	18.9%
Developmental	15.0%	490	3,005	16.3%
Front Line Manager	7.8%	255	1,897	13.4%
Other Positions				
Traffic Manager Coordinator	2.5%	83	566	14.7%
Administrative Manager or Support	1.0%	33	-	-
Operations Manager	1.0%	32	350	9.1%
Misc. such as Ops Support Air Traffic Assistant, Support Specialist, etc.	0.7%	22	-	-
Supervisor, Traffic Management Coordinator	0.5%	15	158	9.5%
Total Other Positions	*5.7*	*185*	-	-
Total		3,246	-	-
Missing	0.7%	22	-	-
Total	100.0%	3,268	-	-

**Note: From FAA Staffing Spreadsheet dated 12/18/2010.*

Table 2-3. Number and Percentage of Respondents in Four Types of Positions

Current Position	% of Respondents	# of Respondents
Certified Professional Controller (CPC)	70.9%	2,316
Developmental	15.0%	490
Front Line Manager	7.8%	255
Other	*5.7%*	*185*
Total	99.3%	3,246
Missing	0.7%	22
Total	100.0%	3,268

The survey of Air Traffic Controllers conducted in 1999 (Della Rocco et al., 2000a) placed respondents in the categories of En Route/Terminal (those who controlled traffic), Flight Service Specialists (FSS)[4], and Management/Staff. Since FSS personnel were not included in the current survey, the two comparable categories of positions in the current survey is a combination of CPC/Developmentals and Front Line Manager/Other, as shown in Table 2-4. When comparing the results with the earlier survey, these two categories will be used

Table 2-4. Position Categories of Della Rocco (2000a) and Comparable Categories in Current Survey

Della Rocco (2000a) Categories	Current Comparable Combined Categories
En Route/Terminal	CPC/Developmental
Flight Service	Not Included
Management/Staff	Front Line Manager/Other

For comparative analysis within the 2010 survey results, it was decided to separate CPCs and Developmentals since Developmentals tend not to have schedules that include midnight shifts. Hence, combining them with CPCs might yield a misleading view of schedule types. It was also decided to separate Front Line Managers from Others since the two groups have different schedules, including differing exposure to midnight shifts.

2.2.1.3 Response Rates by Facility Types

The overall response rates for CPCs in the various facilities are shown in Table 2-5. The response rates were 22.2% in En Route, 18.6% in TRACON, and 15.7% in Tower facilities.

Table 2-5. Response Rates of CPCs for Each Facility Type

Facility Type	Response Rate	Number of Respondents	Total Working	% of Respondents in Sample
En Route	22.2%	1,167	5,262	50.5%
Towers	15.7%	817	5,201	35.3%
TRACON	18.6%	329	1,765	14.2%
Total	18.9%	2,313	12,228	100.0%
Missing		3		
Average/Total	18.9%	2,316	12,228	

2.2.1.4 Facility Characteristics

Approximately 70% of all respondents worked at level 10 facilities or higher, as shown in Table 2-6. The FAA classifies ATC facilities into a series of levels, where a high level number indicates a high volume of traffic and airspace complexity, the highest level being level 12. The largest proportion of

[4] In the 1999 Survey, Traffic Manager Coordinators (TMC) and Traffic Manager Supervisors (TMS) were part of the FSS category, along with those working in Flight Service Stations. Since TMCs and TMSs were not in the 1999 En Route/Terminal category, they were put in the 2010 "Other" category to enable comparison between the 1999 En Route/Terminal category and the 2010 CPC/developmental category.

respondents (32.8%) worked at level 12 facilities, followed by level 11 facilities (21.6%), and level 10 facilities (15.9%).[5]

Table 2-6. Proportion and Number of Respondents at Different Facility Levels		
Facility Level	Percent of Respondents	Number of Respondents
4	0.1%	3
5	2.4%	77
6	4.1%	132
7	7.7%	249
8	6.8%	220
9	7.1%	229
10	15.9%	514
11	21.6%	700
12	32.8%	1,061
Not known	1.6%	52
Total	100.0%	3,237
Missing		31
Total		3,268

A majority of all respondents (89.1%) worked at 24-hour facilities, as shown in Table 2-7. These results are consistent with the finding that most respondents work at level 10 facilities or higher and suggest that most survey respondents have had some exposure to 24-hour shift patterns.

Table 2-7. Proportion and Number of Respondents Working at 24-hour Facilities		
Work at 24-hour Facilities?	Percent of Respondents	Number of Respondents
Yes	89.1%	2,879
No	10.9%	352

[5] Facility levels are those which were in place at the time of the survey prior to the current classifications

Total	100.0%	3,231
Missing		37
Total		3,268

2.2.1.5 Respondents' Age and Experience

The age ranges of the CPCs and Developmentals have a bimodal distribution that matches the pattern in the overall controller workforce. As shown in Table 2-8 the two peaks in respondents' ages were in the 46-50 year age group (24.5%) and in the 26-30 year age group (22.1%). This distribution is similar to that of the general controller workforce as described in the FAA document, *A Plan for the Future: 10 Year Strategy for the Air Traffic Control Workforce 2009-2018* (2009). This similarity suggests that, in terms of age, the survey respondents constitute a representative sample of the larger population of controllers.

Table 2-8. Proportion of CPCs and Developmentals in Different Age Categories

Age Category	Proportion of Respondents	Number of Respondents
25 or under	6.0%	168
26-30	22.1%	619
31-35	13.8%	386
36-40	7.8%	217
41-45	14.1%	395
46-50	24.5%	686
51-55	10.3%	287
56+	1.3%	37
Total	100.0%	2,795
Missing	-	11
Total		2,806

For CPCs and Developmentals, the distribution of years of experience in their current position is also bimodal, as shown in Table 2-9. A large proportion of this group has been in their current position for either 1–4 years (30.2%) or 20–29 years (34.0%). The bimodal distribution is most clearly visible when adding the first three rows together to show that 48.2% of respondents had 0–9 years of experience, 16.7% had 10–19 years of experience, and 34.0% had 20–29 years of experience.

It is noteworthy that 37% of respondents had four years of experience or less in their current position. This possibly reflects their progression through different positions in the course of their careers.

Table 2-9. Years of Experience in Current Position of CPCs and Developmentals

Years of Experience	Proportion of Respondents	Number of Respondents
Less than 1	6.8%	190
1-4	30.2%	843

5-9	11.2%	313
10-19	16.7%	466
20-29	34.0%	949
30+	1.0%	28
Total	100.0%	2,789
Missing	-	17
Total		2,806

Yet another bimodal distribution exists in the total years of CPCs' and Developmentals' professional experience with ATC, as shown in Table 2-10. Adding the first three rows of Table 2-10, it can be seen that 36.4% of these respondents had 0-9 years of professional experience; 18.9% had 10-19 years of experience; and 40.3% had 20-29 years of experience. On the whole, these respondents have been professionally affiliated with ATC for a substantial period of time, with 75.8% reporting five or more years of experience.

Table 2-10. CPCs' and Developmentals' Years of Total Professional Experience with ATC (Including Military ATC experience)

Years of Professional Experience	Percent of Respondents	Number of Respondents
Less than 1	3.0%	84
1-4	21.1%	589
5-9	12.3%	344
10-19	18.9%	529
20-29	40.3%	1,126
30+	4.3%	121
Total	100.0%	2,793
Missing		13
Total		2,806

2.2.1.6 All Respondents' Positions by Age and Experience

Developmentals were the youngest group with 96% under age 35. CPCs were older with 30% under age 35; FLMs and Others both had 5% under 35, as shown in Table 2-11.

Table 2-11. All Respondents' Positions by Age

	Developmental		CPC		FLM		Other		Total	
Age	%	n	%	n	%	n	%	n	%	n
25 or under	22%	110	3%	58		0		0	5%	168
26-30	53%	259	16%	360	2%	6	1%	2	19%	627
31-35	21%	101	12%	285	3%	8	4%	7	12%	401
36-40	2%	9	9%	208	13%	34	4%	7	8%	258
41-45	0%	1	17%	394	19%	48	20%	36	15%	479

46-50	1%	5	30%	681	36%	92	40%	73	26%	851
51-55	0%	2	12%	285	22%	55	27%	50	12%	392
56+	0%	2	2%	35	5%	12	5%	9	2%	58
Total	100%	489	100%	2,306	100%	255	100%	184	100%	3,234
Missing										34
Total										3,268

Developmentals had the fewest years of affiliation with ATC, with 79% having fewer than five years of ATC experience. CPCs are more experienced with 12% having fewer than five years of experience. Only 1% of FLMs and Others had fewer than five years of experience, as shown in Table 2-12.

Table 2-12. All Respondents' Position by Years of Affiliation with ATC (Includes Military)

	Developmental		CPC		FLM		Other		Total	
Years	%	n	%	n	%	n	%	n	%	n
Less than 1	16%	79	0%	5	-	0	-	0	3%	84
1-4	63%	307	12%	282	1%	2	1%	2	18%	593
5-9	12%	60	12%	284	4%	10	1%	2	11%	356
10-19	7%	33	22%	496	24%	61	15%	27	19%	617
20-29	1%	6	49%	1,120	61%	154	66%	122	43%	1,402
30+	0%	2	5%	119	10%	26	17%	31	6%	178
Total	100%	487	100%	2,306	100%	253	100%	184	100%	3,230
Missing										38
Total										3,268

2.2.2 Schedules

2.2.2.1 Shift Start Times—3 Week-Bid Schedules and Week Worked

Figure 2-1 shows the start times in a one-week period of the bid schedules (in dashed red) and the actual work schedules (in solid black) where D = Day, A = Afternoon, and M = Midnight Shifts. All respondents except 106 with administrative schedules (standard business hours between the hours of 07:00 and 18:00 5 days a week) were asked to indicate the start times of each day in their 3-week bid schedules as well as their start times for each day of the week they actually worked in their last full work week. The frequencies of bid schedule start times were divided by 3 to match the times of the actual week worked. The close correspondence between the two measures indicates that the schedules being bid are being worked and adds validity to the schedule data. Figure 2-1 also shows that a relatively low proportion of shifts started between 21:00 and 24:00 (midnight shift) compared to earlier shift start times.

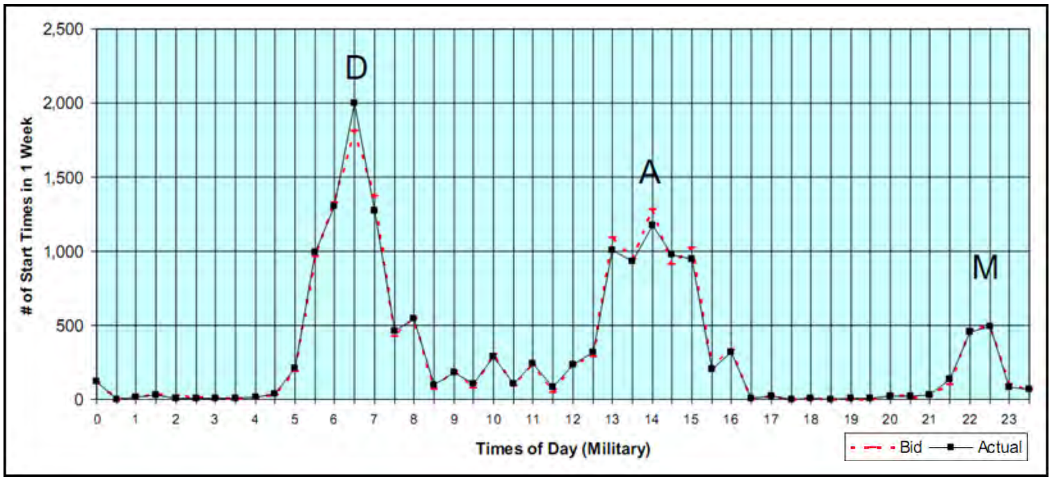

Figure 2-1. Distribution of 15,554.8 shift start times in 1 week of 3-week bid schedules (3 week bid schedule divided by 3) compared with distribution of 15,557 start times in week actually worked.n = 3132 bid schedule, 3083 actual schedule (all respondents except 106 with administrative schedules, and 30 missing data for bid schedule, 79 missing data for actual schedule).

Table 2-13 provides further detail on these shift start times and indicates that only 7.6% of the bid shifts start between 21:00 and 24:00 (midnight shifts). Of the shift start times, 84.2% fall within three 3-hour periods. The greatest proportion of shifts (41.4%) begins between 05:30 and 08:30, followed by 35.2% between 13:00 and 16:00, and 7.6% between 21:00 and 24:00. Hence there is only a small proportion of start times that lead to shift work during the evening circadian trough.

Table 2-13. Proportion and Number of Bid Shift Start Times During Three Shift Time Periods in the Day		
Important 3-hr. Intervals	% of Total Shift Start Times	# of Shift Start Times*
Between 05:30 & 08:30	41.4%	6,439.33
Between 13:00 & 16:00	35.2%	5,473.33
Between 21:00 & 24:00	7.6%	1,177.83
Sub-total	84.2%	13,090.50
All Other Start Times	15.8%	2,464.33
Total Shift Start Times	100.0%	15,554.83

**Shift start times of the 3-week bid schedule are divided by three to compare with those in the actual week worked schedule.*

Table 2-14 provides further detail on the morning start times in Figure 2-1 and indicates that most of the morning start times are between 06:00 and 07:30.

Table 2-14. Proportion and Number of Morning Shift Start Times for the 3-Week Bid Schedule (Divided by 3) and Actual Week Worked				
Shift Start Times	% of Start Times in 3-Week Bid Schedule/3	# of 3-Week Bid Schedules/3	% of Start Times in Week Worked	# of Week Worked
01:00-05:29	5.5%	348.3	5.0%	345.0
05:30-05:59	15.1%	961.3	14.4%	993.0
06:00-06:29	20.8%	1,321.7	18.8%	1,304.0
06:30-06:59	28.5%	1,812.8	28.9%	1,999.0
07:00-07:29	21.6%	1,372.2	18.4%	1,272.0
07:30-07:59	6.7%	425.7	6.7%	463.0
08:00-08:29	8.6%	545.7	7.8%	543.0
Total	100.0%	6,362.0	100.0%	6,919.0

2.2.2.2 Hours Off Between Shifts

About 15.5% (1,718/11,101) of the intervals between bid shifts were only 8-9 hours long; higher frequency peaks occur at 15-16 hours between shifts. Figure 2-2 shows the frequency of hours off between shifts in a one-week period of both bid (in dashed red) and actual week worked schedules (in solid black) from all respondents

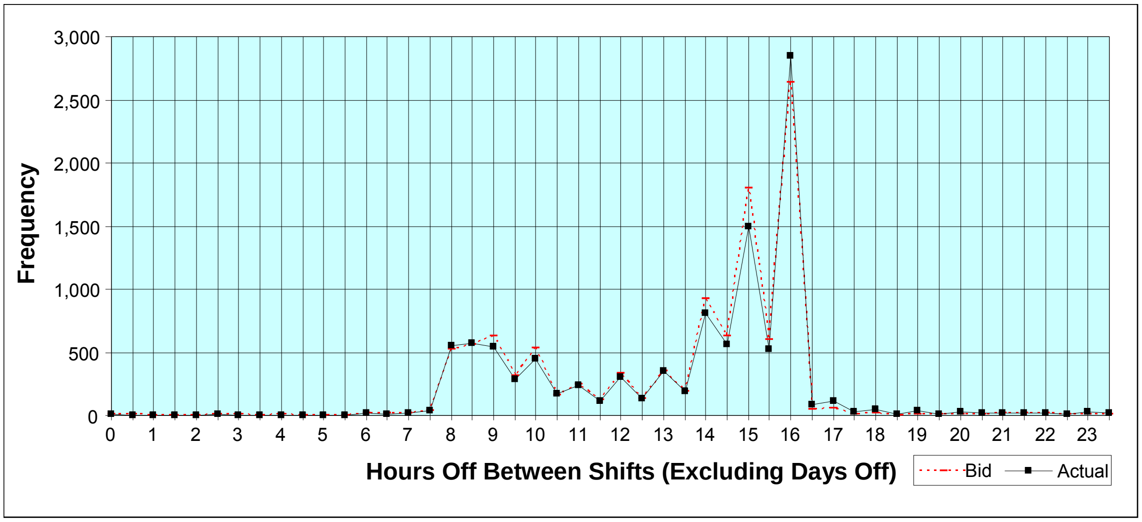

Figure 2-2. Frequency of number of hours off between shifts (excluding days off) in a one-week period for both 3-week bid schedules (divided by three) and actual week worked schedules.n = 11,101.5 bid intervals—33,306/3 and 10,769 actual intervals. n = 3238 bid schedules, 3189 actually worked schedules (30 missing data for bid schedule, 79 missing data for actual schedule.)

Table 2-15 gives additional detail on time off between shifts in Figure 2-2 and indicates that about 25% of the intervals between shifts were less 11 hours. About half (51.8%, 1708/3238) of the survey respondents had at least one quick-turn (8 or 9 hours between shifts) in their described 3-week bid schedules.

Table 2-15. Proportion and Number of Times-Off Between Shifts Of Less than 11 Hours in One Week of Bid Schedules

Hours Between Shifts	% of Shifts in 3-Week Bid Schedule/3	# of 3-Week Bid Schedules/3
8	4.7%	527.0
8.5	5.1%	565.7
9	5.6%	625.2
9.5	2.9%	318.7
10	4.8%	529.3
10.5	1.5%	165.5
Total	24.6%	2,731.3

Note: Three-week bid schedules are divided by three to apply to a one-week period.

2.2.2.3 Rotations

Figure 2-3 shows that among all respondents, the most frequent number of rotations within work weeks (not between weeks) was two per week. This was true for both the actual week worked and the 3-week bid schedule (divided by 3). The 2-2-1 has two rotations per week, from two afternoon shifts to two day shifts to the midnight shift. Figure 2-3 indicates that the number of rotations in the actual schedules is slightly higher than the bid schedules. That is because the bid schedules take into consideration schedules over a three-week period divided by three. Hence the bid schedules can have an *average* number of rotations in one week ending in 0.33, 0.5, or 0.66 as well as the integers

1,2,3,4, and 5. It can be seen that on either side of an actual week worked number (integer), there are bid schedules at non-integer numbers. During an actual work week, they will fall on the integer.

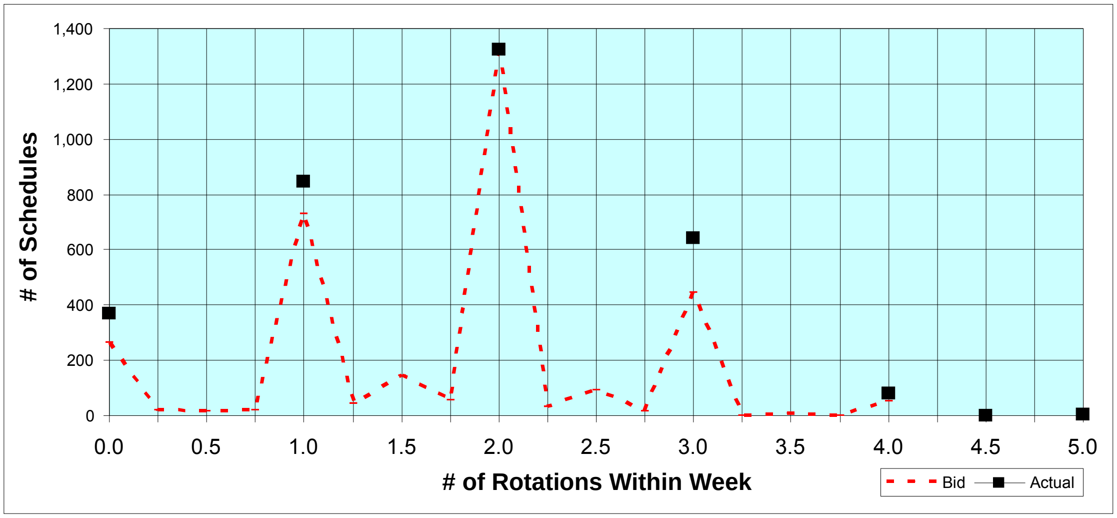

Figure 2-3. Number of rotations within the week actually worked (black squares) and the 3-week bid schedule (dashed red) divided by 3. Note: Rotations are within weeks, not between weeks. n = 3238 bid schedule, 3189 actual schedule (30 missing data for bid schedule, 79 missing data for actual schedule).

Table 2-16 provides more detail on rotations and indicates that over 90% of all respondents' schedules (both 3-week bid schedules and week actually worked) had one or more rotations.

Table 2-16. Number of Rotations Per Week (within Weeks) of 3-Week Bid Schedules (Divided by 3) and Actual Week Worked Schedules

# of Rotations Per Week	*% of 3-Week Bid Schedules*	*# of 3-Week Bid Schedules*	*% of Actual Schedules*	*# of Actual Schedules*
0.0	7.3%	236	9.2%	292
0.33	0.6%	19	0.0%	
0.5	0.5%	15	0.0%	
0.66	0.6%	19	0.0%	
1.0	22.6%	732	26.5%	845
1.33	1.4%	46	0.0%	
1.5	4.5%	146	0.0%	
1.66	1.7%	56	0.0%	
2.0	40.6%	1,316	41.5%	1,324
2.33	1.0%	31	0.0%	
2.5	2.8%	92	0.0%	
2.66	0.5%	17	0.0%	
3.0	13.8%	446	20.2%	643
3.33	0.1%	2	0.0%	
3.5	0.2%	7	0.0%	
3.66	0.0%	1	0.0%	
4.0	1.6%	51	2.5%	79
4.33	0.0%		0.0%	
4.5	0.0%	0	0.0%	0
4.66	0.0%		0.0%	
5.0	0.2%	6	0.2%	6
Total	100.0%	3,238	100.0%	3,189
Missing		30		79
Total		3,268		3,268

2.2.2.4 Midnight Shifts

Figure 2-4 shows that most respondents' schedules did not include a midnight shift. Of those respondents who worked or bid for midnight shifts, the majority of schedules included only one midnight shift per week. Differences between the bid and actual schedules are due to the three-week bid schedules being divided by three to get an average, which can end in 0.33, 0.5, or 0.66. During an actual work week, the numbers are integer values.

Table 2-17 shows details of Figure 2-4. The proportion of actual schedules that had no midnights was higher than the bid schedule since many bid schedules had midnights only every other week.

Table 2-17. Number and Proportion of Midnights in 3-Week Bid Schedules and Actual Week-Worked Schedules

# of Midnights Per Week	*% of 3-Week Bid Schedules*	*# of 3-Week Bid Schedules*	*% of Actual Schedules*	*# of Actual Schedules*
0.0	54.1%	1,752	62.9%	2,007
0.33	2.3%	73		
0.5	8.0%	260		
0.66	1.6%	51		
1.0	30.5%	989	31.0%	990
1.33	0.4%	14		
1.5	0.3%	11		
1.66	0.2%	8		
2.0	1.7%	56	4.7%	151
2.33	0.1%	4		
2.5	0.1%	4		
2.66		0		
3.0	0.2%	7	0.8%	26
3.33		1		
3.5		0		0
3.66		0		
4.0	0.1%	3	0.2%	7
4.33		0		
4.5		0		0
4.66		0		
5.0	0.2%	5	0.3%	8
Total	100.0%	3,238	100.0%	3,189
Missing		30		79
Total		3,268		3,268

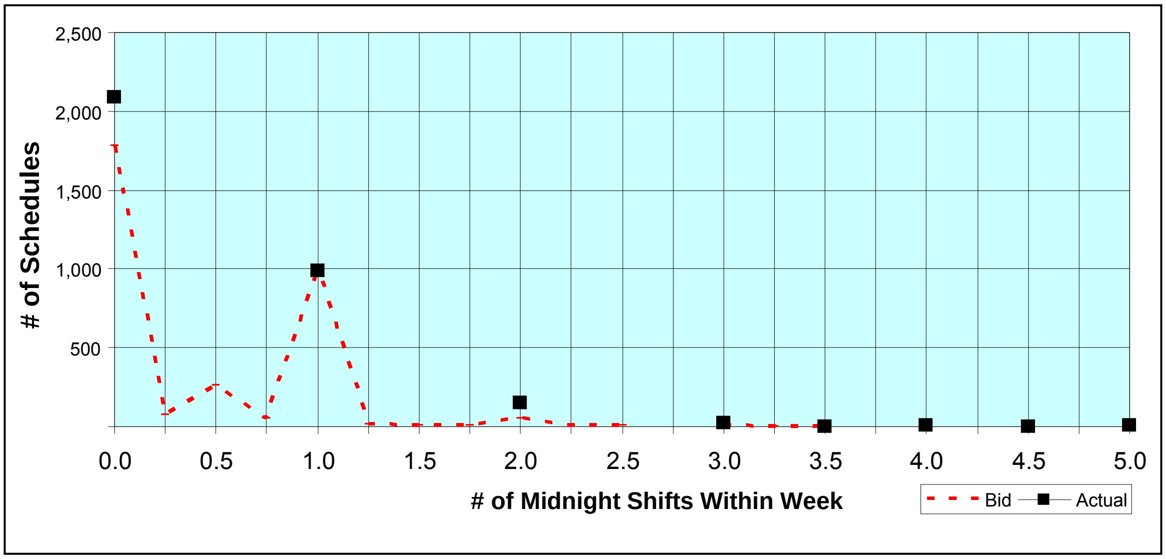

Figure 2-4. Number of midnight shifts (start between 20:00 and 01:00) in the actual week worked (black squares) and the 3-week bid schedule (dashed red) divided by 3. n = 3238 bid schedule, 3189 actual schedule (30 missing data for bid schedule, 79 missing data for actual schedule).

2.2.2.5 Number of Shifts Worked in a Week

Figure 2-5 shows that more respondents reported actually working 6 days in the previous full week of work than were in their reported bid schedules. There were 452 controllers who worked 6 days in a row in their actual schedule. It could be argued that the higher number of those working a 6-day week is a result of respondents working only one or two 6-day weeks in a three-week period. However, 452 is about twice the number of bid schedules containing at least one 6-day week out of three weeks (179), or more than a 6-day week (49) out of three weeks. Whether this additional staffing on the sixth day is accomplished through required and scheduled overtime or short-notice overtime remains to be determined.

Over half (52.9%, 239/452) of those who worked 6-days in a row worked at least one midnight shift, and 15% (68/452) worked two or more midnight shifts.

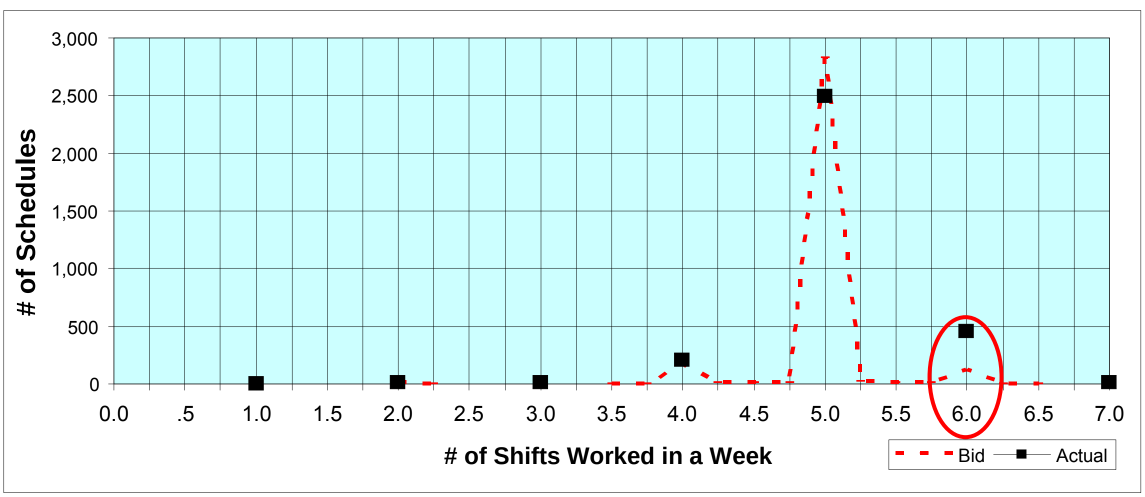

Figure 2-5. Number of shifts in the actual week worked (black squares) and in the 3-week bid schedule (dashed red). n = 3238 bid schedules, 3189 actual schedules (30 missing data for bid schedule, 79 missing data for actual schedule).

Table 2-18 provides more detail on the number of shifts bid versus the actual schedule worked. While only 3.7% of respondents reported bidding for 6-day shift schedules, 14.2% of respondents reported actually working a 6-day schedule in the previous full week worked.

Table 2-18. Proportion and Number of Shifts in the 3-Week Bid Schedule and in the Actual Week Worked				
# of Shifts in a Week	Shifts in Bid Schedule / 3		Actual Schedules	
	%	#	%	#
1.00	0.2%	8	0.1%	3
2.00	0.2%	6	0.3%	9
2.33	0.1%	3	0.0%	
3.00	0.2%	8	0.3%	10
3.50	0.1%	4	0.0%	
3.67	0.0%	1	0.0%	
4.00	5.5%	178	6.6%	209
4.33	0.2%	6	0.0%	
4.50	0.2%	7	0.0%	
4.67	0.4%	12	0.0%	
5.00	87.7%	2,832	78.2%	2,494
5.33	0.8%	25	0.0%	
5.50	0.3%	10	0.0%	
5.67	0.2%	6	0.0%	
6.00	3.7%	119	14.2%	452
6.33	0.0%	1	0.0%	
6.50	0.1%	2	0.0%	
7.00	0.0%	0	0.4%	12
Total	100.0%	3,228	100.0%	3,189
Other		10		
Missing		30		79
Total		3,268		3,268

Note: The number of shifts in a week consists of the number of shifts in the 21-day bid schedules divided by three to enable comparison with the actual days worked. Hence the difference between the 6-day constant schedule defined later as 6-days in a row with a day off between.

Only 7.2% (227/3132) of the respondents had rotating days off. This did not vary by position.

2.2.2.6 Types of Schedules in the 2010 Data

Table 2-19 shows the placement of schedules into five categories. The two largest categories are the same as those for the 1999 survey data. They consist of counterclockwise rapidly rotating schedules without midnights (RR, n = 1335) and with midnights (RRM, n = 1361).

The third category, Straights and Slow Rotations (Days), consists of the schedules considered least likely to be fatiguing, and was designed to serve as a comparison group. This category consists of three types of schedules, none of which contains midnight or rapidly rotating shifts.

- "Administrative Schedules" (standard business hours between the hours of 07:00 and 18:00, 5 days a week, n=106)[6],
- Straight shifts without midnights (n=42)
- Slow rotations without midnights (n=24)

The slow rotations without midnights involve working one week on the same shift and then working a different shift on the following week. This schedule, therefore, does not involve rapid rotations within the week. Both it and the straight shifts without midnights consist of shifts within a normal period of wakefulness. The n for the entire category is 172.

Category 4 was created to examine the impact of 6-day schedules that were constant. Schedules in this "Constant 6-day" category required working 18 days in a 21-day period with a total of 3 days off. Those with these schedules worked exactly six days in a row with one day off between each set of six days. Respondents reported 40 such 6-day bid shifts without midnights and 74 with midnights.

Category 5 contains 10-hour 4-days a week work schedules. There were 167 10-hour schedules of which 138 were rapidly rotating, 20 were straight and 5 were slowly rotating; only 4 included midnights. **Table 2-19 lists the five schedule categories.**

Table 2-19. Five Categories of Bid Schedules and Frequencies

Category	Abbreviation	Description	Percent	Frequency of Bid Schedules
1	RR	Rapid Rotation without Midnights	41.2%	1,335
2	RRM	Rapid Rotation with Midnights	42.0%	1,361
3	Straights & SR (Day)	Straights and Slow Rotations (Day); Administrative (n=106), Other Straights (n=43), & Slow Rotations without Midnights (n=23)	5.3%	172
4	Constant 6-day	RR 6-day without Midnights (n=40) & with Midnights (n=74)	3.5%	114
5	10-hr	10-hr 4-day weeks	5.2%	167
		Other*	2.7%	89
		Total	100.0%	3,238
		Missing		30
		Total		3,268

** "Other" schedules consist of slowly rotating with midnights (n = 10), straight midnights (n = 5), fewer than 10 shifts in 3 weeks (n = 24), and 7 days or over in any one week (n = 49).*

[6] Of those who worked administrative schedules, 31% (33/106) were administrative managers or support personnel and were not operational (see section on administrative schedules). Although the 106 who worked administrative schedules did not work midnight or rotating schedules, they were more likely to work overtime than those with other schedules, somewhat reducing the extent to which this category could serve as an ideal comparison group.

2.2.2.7 Comparison of the 2010 and 1999 Schedule Data

The 2010 schedule data were temporarily re-categorized to fit the definitions of the 1999 schedule categories so as to enable comparison. The definitions of the Straight Shifts and the Straight 5s used for the 1999 data were also used for the 2010 data as follows:

> "The S5 group involved schedules in which individuals worked the same shift for 4-5 days straight, had 1-2 days off, and returned to work a different straight shift the following 4-5 days. The traditional 5-day 2-2-1 was included in the CRM group. The SS group included schedules with the same shift for the entire 21-day period. No schedules with midnight shifts were included in the SS group" (p. 19, Della Rocco et al., 2000a).

As can be seen in Table 2-20, in the 2010 data there is a lower proportion of straight shifts without midnights. There appears to be a higher proportion of counter-clockwise rapidly rotating schedules, especially with midnights, than in the 1999 data. In the 2010 data, there is also lower proportion of slowly rotating one-week schedules both with and without midnights.

Table 2-20. Comparison of 2010 Schedules with 1999 Schedules

1999 Categories	*1999 Schedule Description*	*1999 %*	*1999 #*	*2010 %*	*2010 #*
CR	Counterclockwise Rapidly Rotating without Midnights	29.5%	1,994	40.9%	1,335
CRM	Counterclockwise Rapidly Rotating with Midnights	22.0%	1,486	41.5%	1,361
SS	Straight Shifts without Midnights	10.8%	731	5.2%	169*
S5	Straight 5s Slowly Rotating with & without Midnights	4.6%	313	1.0%	33**
	Subtotal	*67.0%*	*4,524*	*88.5%*	*2,898*
	Other	33.0%	2,230	11.5%	340
	Missing			0.9%	30
	Total	100.0%	6,754	100.0%	3,268

Pearson's Chi Square = 146.2, df 3, p <0.0001 calculated using the subtotals of 4524 and 2872 as column totals (i.e., not including other or missing data).

**20 straight shifts were added to SS from the 10-hour week sample in, since the 1999 categorization included 10-hour straight shifts in its straight shift category (106 Admin, +43 other straights +20 10hour straights = 169).*

***The following were added to S5 from Table 2-15: 23 slowly rotating without midnights from Category 3 (Control) and 10 slowly rotating with midnights from "Other" (10+23 = 33).*

Only 67% of the schedules from the 1999 survey fit into the above categories; 88.5% of the schedules from the 2010 survey fit in the above categories. It is unclear what the 2230 (33%) "Other" schedules consisted of in the 1999 schedule data. This uncertainty makes precise schedule comparisons difficult. In the 2010 data, the 340 (11.5%) that did not fit into the above categories consist of 6-day Constants (n = 114), 10-hour 4-day shifts (without straights) (n = 147), and "Other" from Table 2-19 (n = 89) minus slow rotations with midnights (n = 10).

Examples of common schedules found in each of the four 1999 categories are presented in Table 2-21. The original table is from Della Rocco et al., 2000a (p. 20); the right column has been added to present corresponding data from 2010. The totals for each category are bolded in the two right columns following Della Rocco et al.

Table 2-21. Sample Common Schedules in the 1999 and 2010 Schedule Data

Schedule Type	Shift Schedule Type	Total 1999	Total 2010
1. Straight Shifts (SS)		731	168
	00EEEEEE00EEEEEE00EEEEE	386	16
	00DDDDDD00DDDDDD00DDDDD	84	110
	000EEEE000EEEE000EEEE	48	3

	(10 hour schedule)		
2. Counterclockwise, Rapidly Rotating, without Midnights (CR)		1,994	1,335
	00AAEEE00AAEEE00AAEEE	364	355
	00AAAEE00AAAEE00AAAEE	206	143
	00AABEE00AABEE00AABEE (2-1-2)	187	132
	00AADEE00AADEE00AADEE	131	127
	00AABDE00AABDE00AABDE	66	23
	00AAEEE00AAAEE00AAAEE	43	1
3. Counterclockwise, Rapidly Rotating, with Midnights (CRM)		1,486	1,342
	00AAEEM00AAEEM00AAEEM (2-2-1)	448	503
	00AADEM00AADEM00AADEM	138	102
	00AAEEE00AAEEM00AAEEM (2-3 CR with 2 weeks 2-2-1)	75	5
	00AABEM00AABEM00AABEM	57	47
	00ABEEM00ABEEM00ABEEM	46	87
4. Straight 5s (S5) [Slowly Rotating, with Midnights]		313	34
	00AAAAA00EEEEE00EEEEE	82	7
	00EEEEE00AAAAA00EEEEE	48	5
	00EEEEE00AAAAA00AAAAA	16	5
	00AAAAA00MMMMM00EEEE	10	3

Shift codes:
0 = Day off
E = Early Morning (<0800)
D = Day (0800-0959)
B = Midday (1000-1259)
A = Afternoon (1300-1959)
M = Midnight (2000-0100

2.2.2.8 Comparison of Reported Bid and Actual Schedules in the 2010 data

Figure 2-6 compares the types of bid schedules with the types of actual worked schedules. Again, a higher number of respondents reported that they actually worked the 6-day schedule compared to those who bid for the schedule. Those who transferred to the 6-day shift schedule are the same respondents who bid the rapidly rotating midnight shifts. The 6-day bid schedules were defined as working 6-day schedules (n=114) for the entirety of the three week period (bidding to work 18 of the 21 possible workdays). This does not include those schedules that have one or two 6-day shifts in a 3-week period (n=65) or those schedules that have more than a 6-day shift in a 3 week bid period (n=49). Combining all bid schedules including at least one week of 6-day work schedules accounts for only 50% (228/452) of those who reported actually working a 6-day week indicating that the remaining 50% of those who reported actually working a 6-day week did not bid for this schedule.

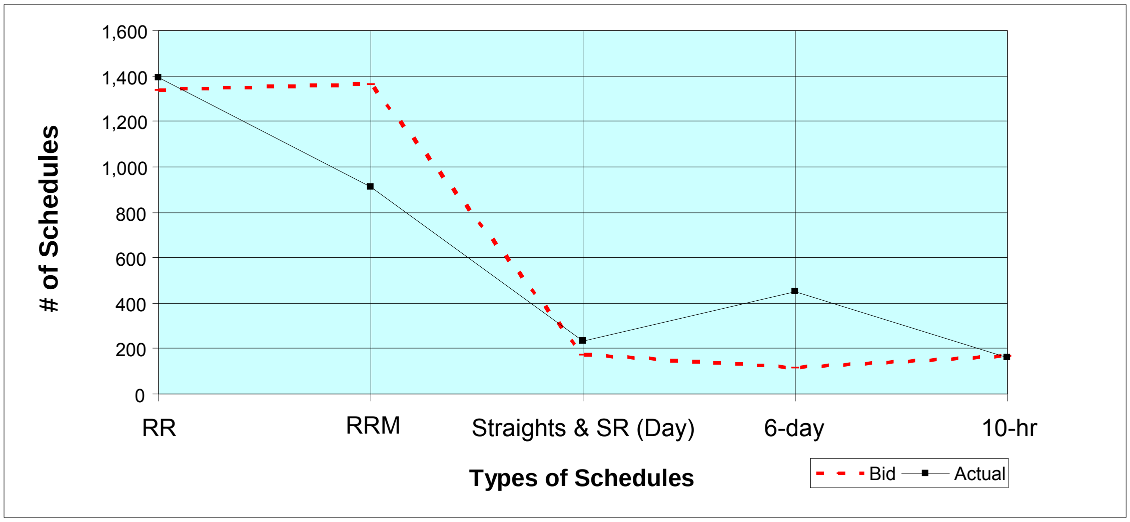

Figure 2-6. Comparison of number of bid schedules and actual schedules reported worked in a week. n = 3238 bid schedules including 89 other; 3189 schedules reported actually worked including 43 other. n = all respondents except for 30 missing on bid schedules and 79 missing on actual schedules.

Table 2-22 provides details on the reported schedules bid and worked.

Table 2-22. Number and Proportion of Reported Schedules Bid and Worked

Type of Schedule	Bid Schedules %	Bid Schedules #	Actual Schedule Worked %	Actual Schedule Worked #
RR	41.2%	1,335	43.7%	1,393
RRM	42.0%	1,361	28.6%	912
Straights & SR (Day)	5.3%	172	7.2%	231
Constant 6-day	3.5%	114	14.2%	452
10hr	5.2%	167	5.0%	158
Other	2.7%	*89*	1.3%	*43*
Total	100.0%	3,238	100.0%	3,189
Missing		30		79
Total		3,268		3,268

Six-day constant schedules may be under-represented on the bid schedule since the sixth day can be required scheduled overtime.

2.2.2.9 Bid and Actual Schedule by Facility

Table 2-23 shows that TRACONs differ from En Route and tower facilities by reporting a higher proportion of 6-day constant bid schedules and a lower proportion of rapidly rotating without midnight schedules.

Table 2-23. Reported Bid Schedule by Facility Type

Type of Schedule	En Route %	En Route #	Tower %	Tower #	TRACON %	TRACON #	Total %	Total #
RR	43.7%	706	43.3%	448	36.1%	163	42.5%	*1,317*
RRM	45.5%	735	39.1%	404	45.5%	205	43.3%	*1,344*
Straights & SR Days	3.4%	55	7.1%	73	7.3%	33	5.2%	*161*
6-day	1.8%	0	3.8%	39	10.2%	46	0	*114*
10-hr	5.6%	91	6.8%	70	0.9%	4	5.3%	*165*
Total	100.0%	1,616	100.0%	1,034	100.0%	451	100.0%	3,101

Note: Pearson's Chi-Square = 121.2, df 8, p <0.0001

The actual work schedules reported are shown in Table 2-24 and indicate that about a third of TRACON personnel are working a 6-day week in a given week—a higher proportion than personnel at the other facilities. Of these, about two thirds (92/138) also reported working midnight shifts. The reported number of respondents actually working 6-day schedules was higher than the number of respondents bidding 6-day schedules across all facility types. The schedules that show a corresponding drop from Table 2-23 to Table 2-24 are the RRM.

Table 2-24. Actual Schedule by Facility Type								
Type of Schedule	En Route		Tower		TRACON		Total	
	%	#	%	#	%	#	%	#
RR	43.8%	701	47.1%	494	40.7%	184	44.5%	1,379
RRM	35.2%	563	24.2%	254	19.5%	88	29.2%	905
Straights & SR Days	4.6%	74	9.7%	102	8.8%	40	7.0%	216
6-day	11.3%	180	11.9%	125	30.5%	138	14.3%	443
10-hr	5.1%	81	7.0%	73	0.4%	2	5.0%	156
Total	100.0%	1,598	100.0%	1,048	100.0%	452	100.0%	3,098

Note: Pearson's Chi-Square = 197.4, df 8, p <0.0001

2.2.2.10 Bid and Actual Schedule by Position

As can be seen in Table 2-25, more than half (54%) of the CPCs reported having bid schedules that are rapidly rotating with midnights. **The FLMs' reported bid schedules are similar to the CPCs', except for a lower proportion of schedules with midnight shifts.** A higher proportion of CPCs than other personnel have 10 hour 4-day a week schedule. Those in all positions have a similar proportion of 6-day constant shifts. Most of the Developmentals have rapidly rotating schedules without midnights.

Table 2-25. Reported Types of Bid Schedules by Position								
Type of Schedule	CPCs		Developmentals		FLMs		Total	
	%	#	%	#	%	#	%	#
RR	32.4%	722	85.3%	400	46.2%	116	42.0%	1238
RRM	53.9%	1202	5.1%	24	43.0%	108	45.2%	1334
Straights & SR Days	3.2%	72	5.8%	24	5.2%	13	3.8%	112
6-day	3.8%	85	3.4%	16	3.6%	9	3.7%	110
10-hr	6.7%	149	0.4%	2	2.0%	5	5.3%	156
Total	100.0%	2230	100.0%	469	100.0%	251	100.0%	2950

Note: Pearson's Chi Square = 506.31, df 8, p <0.0001

Table 2-26 shows the reported types of schedule in the actual week worked by position.

Type of Schedule	CPCs %	CPCs #	Developmentals %	Developmentals #	FLMs %	FLMs #	Total %	Total #
RR	36.0%	802	79.5%	376	50.0%	123	44.1%	1,301
RRM	37.0%	824	3.2%	15	24.0%	59	30.5%	898
Straights & SR Days	4.6%	103	9.3%	44	8.5%	21	5.7%	168
6-day	15.9%	355	7.6%	36	15.0%	37	14.5%	428
10-hr	6.5%	144	0.4%	2	2.4%	6	5.2%	152
Total	100.0%	2,228	100.0%	473	100.0%	246	100.0%	2,947

Table 2-26. Reported Types of Schedule in the Actual Week Worked by Position

Note: Pearson's Chi-Square = 388.3, df 8, p <0.0001

2.2.2.11 Satisfaction with Schedule Types

Figure 2-7 indicates that respondents with the 6-day constant schedule were least satisfied with their schedule—significantly less so than those with the rapidly rotating midnight schedules. Respondents were most satisfied with the 10-hour 4-day schedule and the straights and slowly rotating schedules. When considering CPCs separately, the 10-hour 4- day schedules were rated significantly higher than the Straights and SR (Day) schedules (means 3.44 versus 3.0, p =0.03). CPCs rated the 6-day Constant schedule similarly to all respondents, significantly lower than the other schedules, as portrayed below.

For all respondents, both the 10-hour 4-day schedule and the Straights and Slowly Rotating (days) schedule yielded a higher degree of satisfaction than the rapidly rotating without midnight schedule.

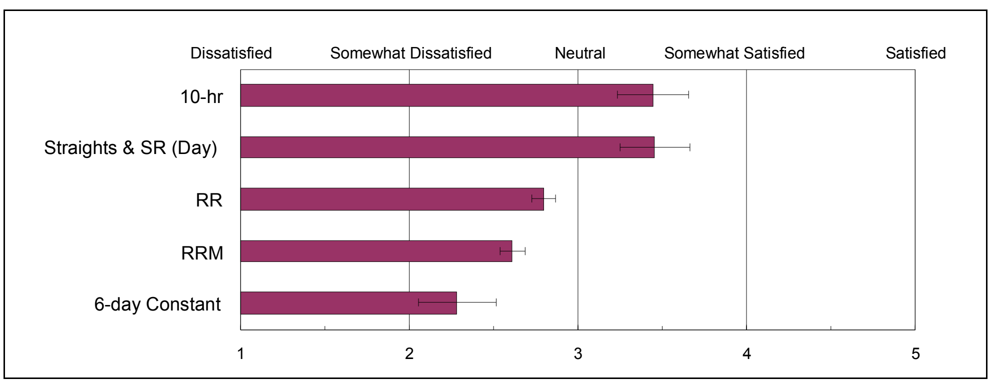

Figure 2-7. Level of satisfaction or dissatisfaction with schedules by all respondents. n = 164 for 10 hour, 165 for Straights & Slowly Rotating (Day), 1316 for Rapidly Rotating, 1347 for Rapidly Rotating with Midnights, and 113 for the 6-day Constant Schedules. Error bars = 95% Confidence Intervals.

2.2.2.12 Schedule Type Related to Operational Events

Table 2-27 indicates that 31.6% of those with the 6-day constant schedule reported that they had an operational event in the last year — a higher proportion than those on other schedules, which averaged 17%. Of those who had rapidly rotating shifts with midnights, 19% reported they had an operational event in the last year. Operational events consisted of an operational error, proximity event, or an operational deviation.

Table 2-27. Proportion and Number of Operational Events by those with Different Bid Schedule Types			
	Had Operational Event		*Total # of Respondents with Schedule Type*
Type of Schedule	*%*	*#*	
Rapidly Rotating	16.0%	210	1,316
RRM	19.3%	260	1,346
Control	15.0%	25	167
Constant 6-day	31.6%	36	114
10-hr 4-Day	14.0%	23	164
Average/Total	17.8%	554	3,107

Note: Pearson's Chi-Square = 22.44, df 4, p <0.0001

2.2.2.13 Schedule Type Related to Age

Table 2-28 indicates that 27% of those working the 6-day Constant schedule are between the ages of 46 and 50 years.

Table 2-28. Proportion of Each Schedule Type Worked by Different Age Groups of Controllers

Age	RR		RRM		Straights & SR Days		6-day		10-hr		Totals	
	%	#	%	#	%	#	%	#	%	#	%	#
≤25	9.1%	121	1.8%	25	5.4%	9	4.4%	5	2.4%	4	5%	164
26-30	27.1%	359	14.6%	197	12.5%	21	16.8%	19	9.0%	15	19.6%	611
31-35	14.3%	189	11.5%	155	7.7%	13	12.7%	15	9.0%	15	12.4%	387
36-40	6.3%	84	10.4%	141	5.4%	9	6.2%	7	6.0%	10	8.0%	251
41-45	10.6%	141	17.5%	237	16.7%	28	19.5%	22	21.7%	36	14.9%	464
46-50	20.9%	277	29.9%	404	32.7%	55	27.4%	31	31.9%	53	26.2%	820
51-55	9.7%	129	13.0%	176	14.9%	25	11.5%	13	16.3%	27	11.8%	370
56+	1.8%	24	1.3%	18	4.8%	8	0.9%	1	3.6%	6	1.8%	57
Total	100%	1,324	100%	1,353	100%	168	100%	113	100%	166	100%	3,124

Note: Pearson's Chi-Square = 246.114, df 28, p <0.0001

Table 2-29 suggests that in general, younger ATC personnel worked schedules with fewer midnights than did older personnel. (Table 2-29 shows the same data as Table 2-28 but with rows totaling 100% instead of columns.)

Table 2-29. Proportion of Schedule Types Worked by Different Age Groups												
Age	RR		RRM		Straights & SR Days		6-day		10-hr		Totals	
	%	#	%	#	%	#	%	#	%	#	%	#
≤25	73.8%	121	15.2%	25	5.5%	9	3.0%	5	2.4%	4	100%	164
26-30	58.8%	359	32.2%	197	3.4%	21	3.1%	19	2.5%	15	100%	611
31-35	48.8%	189	40.1%	155	3.4%	13	3.9%	15	3.9%	15	100%	387
36-40	33.5%	84	56.2%	141	3.6%	9	2.8%	7	4.0%	10	100%	251
41-45	30.4%	141	51.1%	237	6.0%	28	4.7%	22	7.8%	36	100%	464
46-50	33.8%	277	49.3%	404	6.7%	55	3.8%	31	6.5%	53	100%	820
51-55	34.9%	129	47.6%	176	6.8%	25	3.5%	13	7.3%	27	100%	370
56+	42.1%	24	31.6%	18	14.0%	8	1.8%	1	10.5%	6	100%	57
Total	42.4%	1,324	43.3%	1,353	5.4%	168	3.6%	113	5.3%	166	100%	3,124

Note: Pearson's Chi-Square = 246.114, df 28, p <0.001.

Table 2-30 shows that CPCs under age 36 work significantly fewer midnight shifts than CPCs age 36 and above. This analysis focuses solely on CPCs.

Table 2-30. Midnight Shift Work of CPCs Under 36 Years of Age Compared to CPCs Age 36 and Above				
Age	Have Midnight Shift		Total	
	%	#	%	#
Under 36	52.9%	372	100.0%	*703*
36 - 55	58.7%	920	100.0%	1,568
Averages/Totals	56.9%	1,292	100.0%	2,271

Note: Pearson's Chi Square = 6.6, df 1, p = 0.01.

2.2.2.14 Working Over 40 Hours per Week

In addition to the data calculated from the 3-week bid schedules and actual week worked, a separate survey question asked, "In general, about how many hours a week do you work—including overtime?" The responses give a more detailed idea of the hours worked by various groups in the sample.

Half (50.5%) of the CPCs at TRACONs reported working over 40 hours a week compared to 14% of En Route and 21% of Tower personnel, as shown in Table 2-31. This difference is significant. It confirms the results obtained earlier from analyzing the bid and actual schedules worked.

Table 2-31. Number and Percentage of Operational Personnel Who Reported Working Over 40 Hours a Week by Facility Type			
Facility Type	% of CPCs Working Over 40 Hrs/Wk	# of CPCs Working Over 40 Hrs/Wk	Total # of CPCs
En Route	14.4%	168	1,164
Tower	21.1%	172	817
TRACON	50.5%	166	329
Average/Totals	21.9%	506	2,310

Note: Pearson's Chi-Square = 195.1, df 2, p <0.0001

About 25% of all respondents reported worked over 40 hours a week including overtime, as shown in Table 2-32.

Table 2-32. Number of Hours Worked Per Week (Including Overtime) by All Respondents		
Hours Worked	% of Respondents	# of Respondents
20 or less	0.7%	22
21-25	0.1%	2
26-30	0.2%	5
31-35	0.2%	6
36-39	0.1%	4
40	74.0%	2,415
41-45	13.6%	444
46-50	10.0%	326
51-55	0.7%	23
Over 55	0.5%	17
Total	100.0%	3,264
Missing		4
Total		3,268

About 22% (507/2313) of CPCs reported working over 40 hours per week including overtime, as shown in Table 2-33. About 12% (275/2313) reported working over 45 hours per week and 1% (25/2313) over 50 hours per week.

Table 2-33. Number of Hours Reported Working Per Week (Including Overtime) by CPCs		
Hours Worked	% of CPCs	# of CPCs
20 or less	0.6%	13
21-25	0.0%	0
26-30	0.2%	4
31-35	0.2%	4
36-39	0.2%	4
40	77.0%	1,781
41-45	10.0%	232
46-50	10.8%	250
51-55	0.6%	15
Over 55	0.4%	10
Total	100.0%	2,313
Missing		3
Total		2,316

About 68% of FLMs and 84% of operations managers reported working over 40 hours per week as shown in Table 2-34. Only 8.6% of Developmentals worked over 40 hours per week.

Table 2-34. Positions of Those Reported Working Over 40 Hours per Week			
Position	% Working over 40 Hours/Week	# Working Over 40 Hours/Week	Total
Operations Manager	84.4%	27	32
Front Line Manager	68.2%	174	255
Administrative Manager or support	54.5%	18	33
Supervisor, Traffic Management Coordinator	53.3%	8	15
Other	36.4%	8	22
Traffic Management Coordinator	26.5%	22	83
CPC - Oceanic	25.9%	15	58
CPC - Domestic	21.8%	492	2,258
Developmental - Oceanic	13.3%	2	15
Developmental - Domestic	8.4%	40	475
Average and Totals	24.8%	806	3,246
Missing		4	22
Average and Totals	24.8%	810	3,268

2.2.2.15 Administrative Schedules

Table 2-35 shows that all of the administrative managers and their support personnel worked an administrative schedule, but that very few others did.

Table 2-36 indicates that compared to others, those with administrative schedules more frequently reported working over 40 hours per week. Since those with administrative schedules comprise over half of those in the "Straights and SR Day" schedule, this schedule type was somewhat less likely to function as a baseline or ideal schedule type.

Table 2-35. Proportion and Number who Reported Working Administrative Schedules (Between the Hours of 0700 and 1800 Five Days a Week) by Position

Position	% Working Admin. Schedule	# Working Admin. Schedule	Total in Position
Administrative Manager or support	100.0%	33	33
Other	40.9%	9	22
Operations Manager	18.8%	6	32
Supervisor, Traffic Management Coordinator	13.3%	2	15
Developmental - Oceanic	6.7%	1	15
Developmental - Domestic	5.7%	27	475
Front Line Manager	4.3%	11	255
Traffic Management Coordinator	1.2%	1	83
CPC- Domestic	0.4%	10	2,258
CPC- Oceanic	0.0%	0	58
Total	3.1%	100	3,246
Missing			22
Total			3,268

Table 2-36. Those with Administrative Schedules Compared to Others on Working Over 40 Hours a Week			
Facility Type	*% Working Over 40 Hrs/Wk*	*# Working Over 40 Hrs/Wk*	*Total #*
Administrative schedule	46.7%	49	105
Not an administrative schedule	24.1%	761	3,159
Average/Totals	24.8%	810	3,264

Note: Pearson's Chi-Square = 27.8, df 1, p <0.0001

2.2.2.16 Number of Midnight Shifts by Position

Table 2-37 shows that oceanic CPCs reported having the highest average number of midnight shifts in three weeks, followed by domestic CPCs and FLMs. Midnight shifts are defined as those that start between 20:00 and 01:00.

Table 2-37. Mean Number of Midnight Shifts in 3-week Bid Schedules by Position

Position	Mean	N
CPC- Oceanic	2.62	58
CPC- Domestic	1.60	2,243
Front Line Manager	1.20	254
Other	1.00	21
Developmental - Oceanic	0.70	15
Traffic Management Coordinator	0.45	82
Supervisor, Traffic Management Coordinator	0.30	15
Developmental - Domestic	0.16	464
Administrative Manager or support	0.00	33
Operations Manager	0.00	31
Total	1.30	3,216
Missing		52
Total		3,268

2.2.3 Workload-related Fatigue

2.2.3.1 On-the-Job Training (OJT)

Two thirds of the CPCs reported providing on-the-job training. The GAO (2009) identified OJT as a possible contributor to controller fatigue. About one third (32%) of CPC respondents provided OJT between 1 and 9 hours a week, another third (35%) provided OJT 10 hours or more per week, and only one third of the CPCs did not provide OJT, as shown in Table 2-38.

Table 2-38. Proportion and Number of CPCs

Providing Varying Hours of OJT Per Week		
Hours/Week Providing OJT	% of CPCs	# of CPCs
0	33.1%	749
1-4	15.1%	342
5-9	16.7%	379
10-14	15.8%	358
15-19	11.0%	250
20-24	6.0%	135
25 & over	2.3%	51
Total	100.0%	2264
Missing		52
Total		2,316

About 91% of the Developmentals reported typically receiving OJT. About 40% of Developmentals received between 10 and 19 hours per week of OJT, about 30% received 20 hours or more per week, and about 20% received under 10 hours per week; only about 9% of developmentals received no OJT as shown in Table 2-39.

Table 2-39. Proportion and Number of Developmentals Who Reported Receiving Varying Hours of OJT Per Week

Hrs/Week Receive OJT	*% of Developmentals*	*# of Developmentals*
0	9.3%	45
1–4	6.6%	32
5–9	15.3%	74
10-14	19.4%	94
15-19	20.8%	101
20-24	21.0%	102
25 & over	7.6%	37
Total	100.0%	485
Missing		5
Total		490

Most (84.3%) Developmentals reported being certified on one or more positions, as shown in Table 2-40.

Table 2-40. Proportion and Number of Developmentals Certified on One or More Positions		
Certification	% of Developmentals	# of Developmentals
Certified on One or More Positions	84.4%	391
Not Certified on One or More Positions	15.6%	72
Total	100%	463
Missing		27
Total		490

2.2.3.2 Workload/Staffing

Figure 2-8 indicates that CPCs, Developmentals, and FLMs reported that they could usually "keep up with their workload". However, CPCs did not always perceive staffing levels as adequate. When CPCs were asked to indicate whether there were enough qualified controllers on their shifts to do the work safely, their average rating was 3.5 on a scale of 1-5 (between "Sometimes" and "Usually").

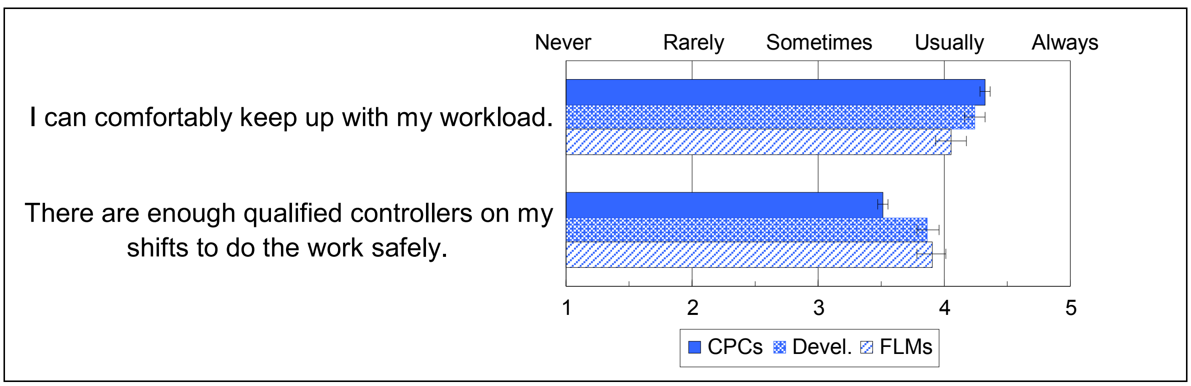

Figure 2-8. Respondents in three job categories rate workload and adequacy of staffing on their shifts. (n = CPCs 2295, Developmentals 473-477, FLMS 221-222.) Error bars = 95% Confidence Intervals.

Figure 2-9 indicates that CPCs from TRACONs were less likely to perceive staffing levels as adequate compared to CPCs from other facilities. CPCs across all domains indicated that they were "usually" able to comfortably keep up with their workload.

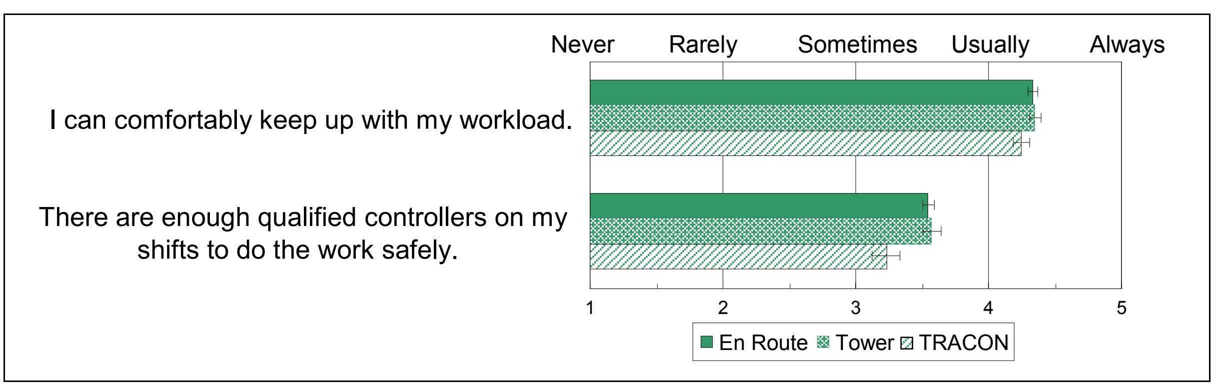

Figure 2-9. CPCs from three facility types rate workload and adequacy of staffing on their shifts. (n = En Route 1161, Tower 806-9, TRACON 324-7.) Error bars = 95% Confidence Intervals.

2.2.3.3 Supervisor Support, Staffing Support, and Fatigue Safety Culture

Figure 2-10 indicates that respondents in all three positions feel that their supervisors support them in work-related activities. Work-related activities include providing a support person or decombining a position if requested and if staffing permits.

Respondents in all three positions see less support from their supervisors in providing fatigue-relieving breaks or rotations when requested. These respondents also report that they are less comfortable asking for such breaks or rotations than asking for assistance for work-related activities. Figure 2-10 also indicates that there might not be enough staffing to allow for fatigue-relieving measures such as providing a support person or decombining a position. The average rating for respondents in all three positions on "There is enough staffing to enable a position to be decombined" was between "Sometimes" and "Frequently" (3.4). These respondents indicate that it isn't often (between "rarely" and "sometimes") that they have to work without a support person when they feel they need one (2.8) or in a combined position that they feel should be decombined (2.6).

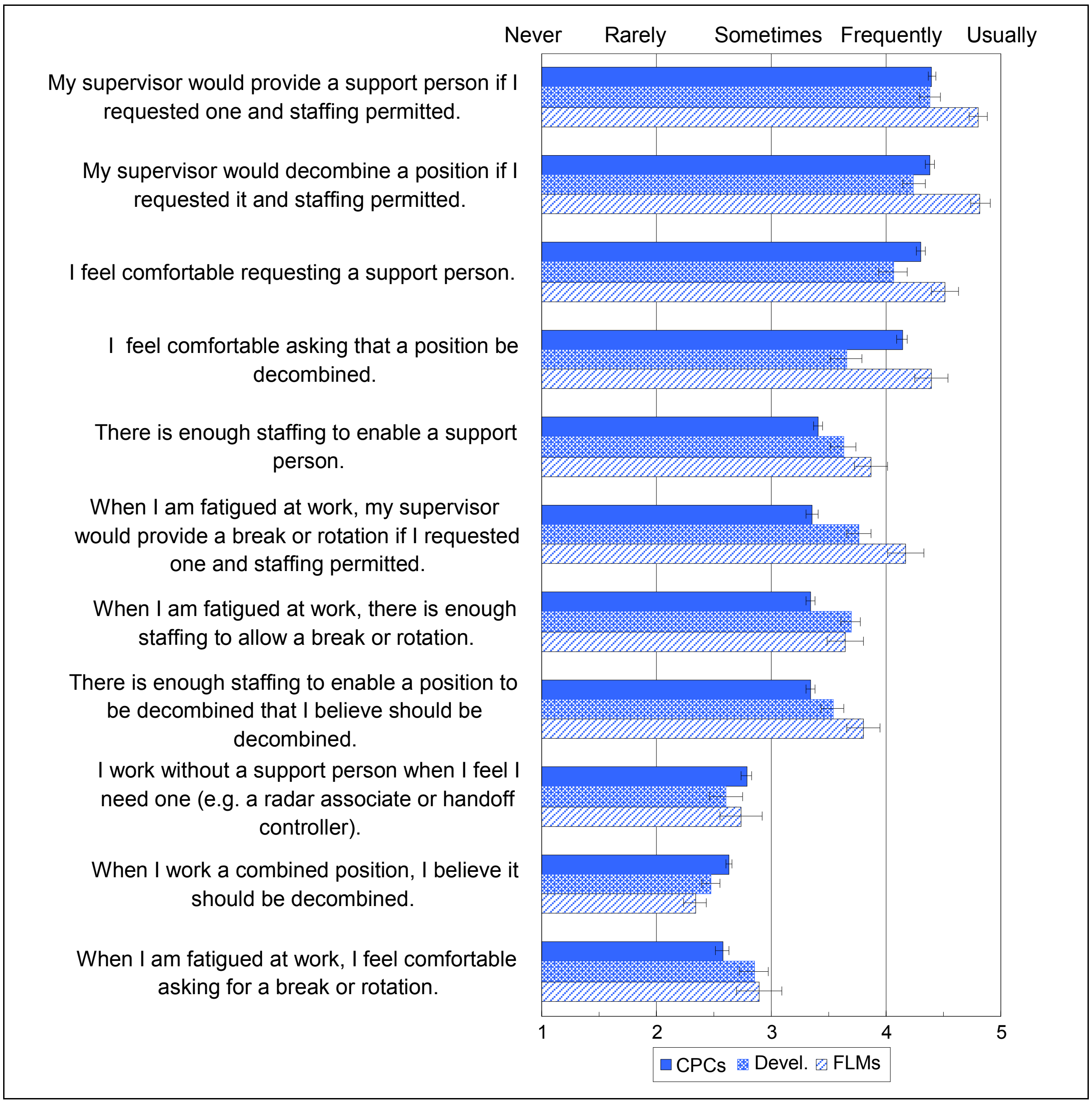

Figure 2-10. Respondents in three job categories rate supervisor support, staffing, and fatigue safety culture. (n = 2163-2296 CPCs, 301-472 Developmentals, 171-217 FLMs.) Error bars = 95% Confidence Intervals

Figure 2-11 shows differences in the three facility types regarding perceived supervisor support, staffing, and fatigue safety culture. En Route CPCs perceived the most supervisory support regarding work activities and felt most comfortable requesting this support. TRACON CPCs indicate a higher rate of staffing problems, a higher rate of working without a support person when they feel they need one, or working a combined position when they feel it should be decombined. When fatigued, CPCs from Towers indicate a higher frequency of supervisors providing breaks if requested and more comfort in asking for these breaks.

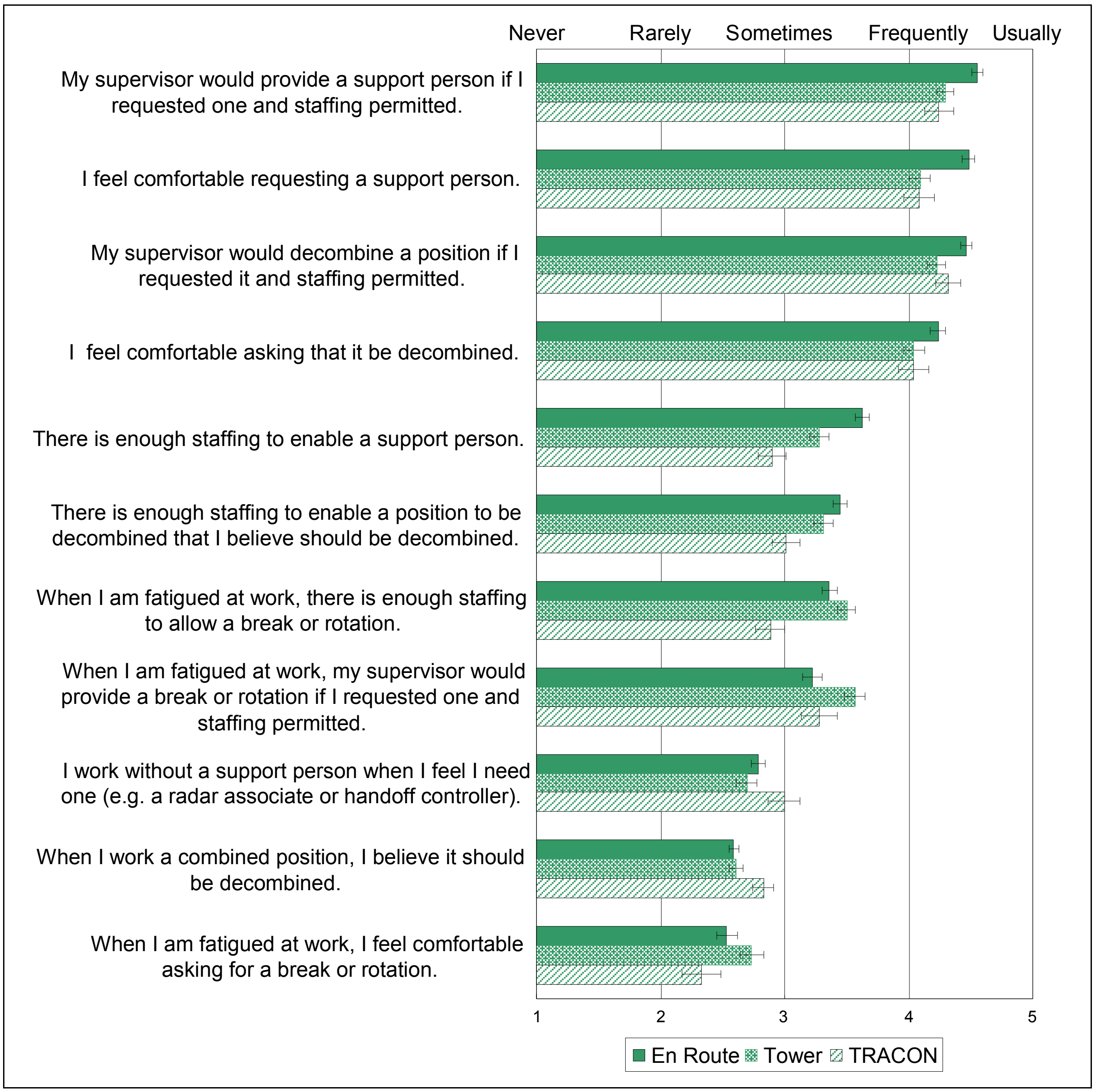

Figure 2-11. CPCs from three facility types rate supervisor support, staffing, and fatigue safety culture. (n = En Route 1131-1163, Tower 702-813, TRACON 309-324.) Error bars = 95% Confidence Intervals.

2.2.4 Rotation and Breaks

CPCs indicate that position rotations utilized to reduce fatigue are "somewhat adequate"; FLMs indicate that they are more adequate, as shown in Figure 2-12.

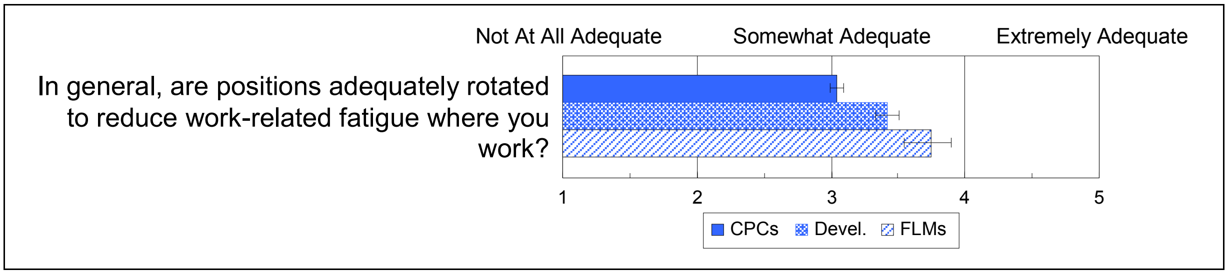

Figure 2-12. Respondents in three job categories rate adequacy of position rotation to reduce fatigue. (n = 2288 CPCs, 468 Developmentals, 214 FLMs.) Error bars = 95% Confidence Intervals.

Of all the CPCs, those from TRACONs rate position rotations for reducing fatigue as least adequate; CPCs from Towers rate the rotation as most adequate, as shown in Figure 2-13.

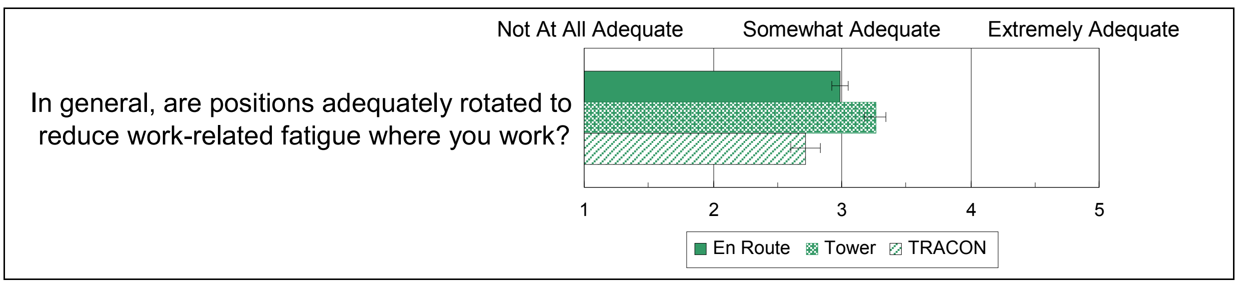

Figure 2-13. CPCs from three facility types rate adequacy of rotation to reduce work-related fatigue. (n = 1152 En Route, 809 Tower, 326 TRACON.) Error bars = 95% Confidence Intervals.

Table 2-41 shows that most non-meal breaks are reported to be between 10 and 50 minutes long. Respondents were asked, "On average, about how long are your breaks (non-meal)?" FLMs reported a higher proportion of non-meal breaks less than 20 minutes in length (about 17% as opposed to 4% and 7% for the CPCs and Developmentals respectively).

Table 2-41. Reported Length of Non-Meal Breaks by Position

	CPCs		Developmentals		FLMs	
Break Length	%	#	%	#	%	#
Under 10 minutes	0.1%	3	0.2%	1	8.6%	22
10-19 minutes	4.3%	100	6.9%	34	8.6%	22
20-29 minutes	41.5%	961	39.8%	195	20.0%	51
30-39 minutes	39.3%	910	39.8%	195	31.0%	79
40-49 minutes	10.8%	250	9.6%	47	13.7%	35
50-59 minutes	2.7%	63	1.2%	6	2.0%	5

60+ minutes	0.8%	19	0.8%	4	0.8%	2
Missing	0.4%	10	1.6%	8	15.3%	39
Total	100.0%	2,316	100.0%	490	100.0%	255

Figure 2-14 shows these data as an average reported length of break time. FLM reported breaks are significantly shorter than CPCs, but not than Developmentals.

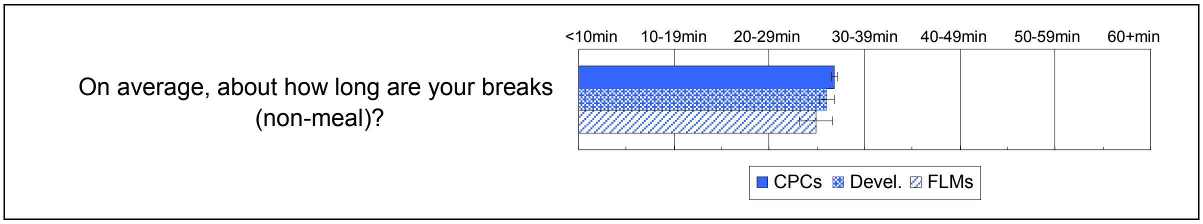

Figure 2-14. Average reported non-meal break time by position. (n = 2306 CPCs, 482 Developmentals, 214 FLMs.) Error bars = 95% Confidence Intervals.

Figure 2-15 indicates shorter reported non-meal break times for CPCs from TRACONs than from the other facilities.

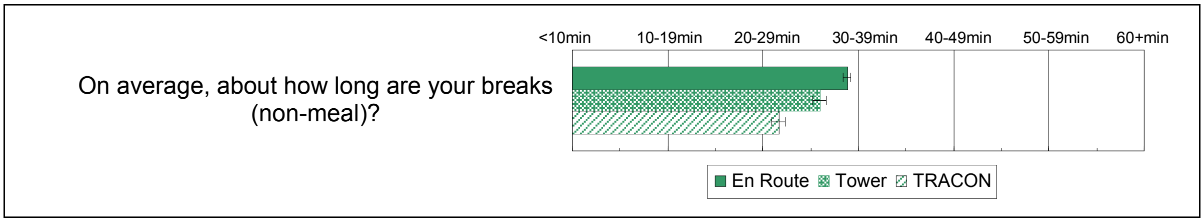

Figure 2-15. Average CPC reported non-meal break time by facility. (n = 1164 En Route, 813 Tower, 328 TRACON) Error bars = 95% Confidence Intervals.

As can be seen in Table 2-42, most reported breaks occur between every 1 hour and 15 minutes and 1 hour and 30 minutes. Respondents were asked, "On average, how frequently do you have breaks when you are on position?" A high proportion of FLM responses are missing (21%), indicating that this question may not have been relevant for them. Another 20% of FLMs indicated that their breaks occurred every 2.5 hours or longer.

Table 2-42. Frequency of Reported Breaks by Position

	CPCs		Developmentals		FLMs	
Break Frequency	%	#	%	#	%	#
Every 30 min. or less	0.1%	3	0.4%	2	0.0%	0
Every 45 min.	0.5%	12	1.2%	6	1.6%	4
Every 1 hr.	7.5%	174	11.6%	57	7.8%	20
Every 1 hr. 15min.	28.8%	666	30.2%	148	16.9%	43
Every 1 hr. 30 min.	39.3%	911	35.3%	173	19.2%	49
Every 1 hr. 45 min.	14.6%	339	9.8%	48	6.7%	17
Every 2 hrs.	6.4%	148	7.6%	37	5.5%	14
Every 2 hrs. 15 min.	0.6%	15	0.2%	1	1.2%	3
Every 2 hrs. 30 min. or more	0.7%	17	0.2%	1	20.0%	51
Missing	1.3%	31	3.5%	17	21.2%	54

Total	100.0%	2,316	100.0%	490	100.0%	255

Figure 2-16 shows the averages of these responses and indicates that the average reported time between breaks is less than 90 minutes for CPCs and Developmentals, but significantly longer for FLMs.

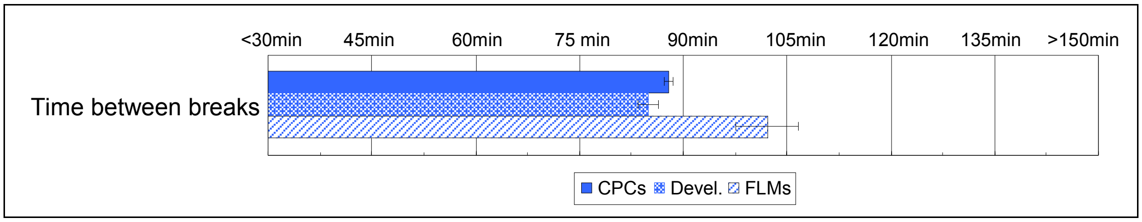

Figure 2-16. Responses to "On average, how frequently do you have breaks when you are on position?" by position. (n = 2285 CPCs, 473 Developmentals, 201 FLMs.) Error bars = 95% Confidence Intervals.

Figure 2-17 indicates that the average reported time between breaks for CPCs is less than 90 minutes for En Route and TRACON.

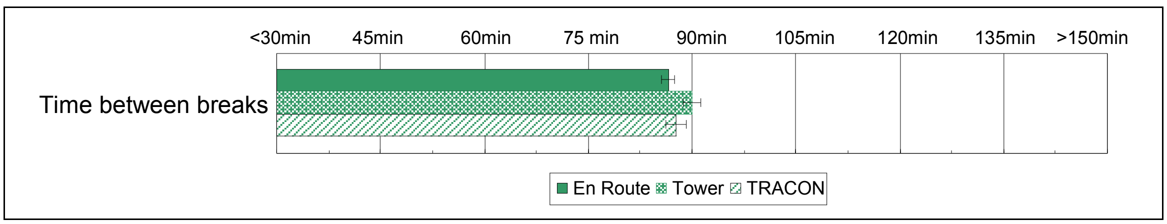

Figure 2-17. CPC responses to "On average, how frequently do you have breaks when you are on position?" by facility type. (n = 1157 En Route, 806 Tower, 321 TRACON) Error bars = 95% Confidence Intervals.

Table 2-43 indicates that 76% of CPCs reported feeling that more breaks could safely be taken during low workload periods compared to 51% of FLMs. Conversely, over 25% of FLMs did not feel that more breaks could be taken during low workload periods.

Table 2-43. Responses to "Do you feel that more breaks could be safely taken during low workload periods?" by Position

	Yes		No		N/A Don't know		Total
Positions	%	#	%	#	%	#	#
CPCs	76.1%	1,751	7.7%	177	16.2%	373	2,301
Developmentals	59.5%	289	5.1%	25	35.4%	172	486
FLMs	50.6%	121	25.5%	61	23.8%	57	239
Total	71.4%	2,161	8.7%	263	19.9%	602	3,026

Note: Pearson's Chi-Square = 195.1, df 4, p <0.0001.

Table 2-44 below indicates that 85% of CPCs in En Route facilities felt that breaks could be safely taken during periods of low workload compared to Towers (66%) and TRACONs (72%).

Table 2-44. CPCs' Responses to "Do you feel that more breaks could be safely taken during low workload periods?" by Position							
	Yes		No		N/A Don't know		Total
Facilities	%	#	%	#	%	#	#
En Route	84.7%	982	3.4%	39	11.9%	138	*1,159*
Tower	65.6%	534	13.1%	107	21.3%	173	*814*
TRACON	71.6%	234	9.5%	31	19.0%	62	*327*
Average/Totals	76.1%	1,750	7.7%	177	16.2%	373	2,300

Note: Pearson's Chi-Square = 112.5, df 4, p <0.0001.

Of those who responded that more breaks could be safely taken during periods of low workload, Table 2-45 indicates that about 36% of CPCs, 31% of FLMs, and 18% of Developmentals felt that these conditions could occur 7 or more times a week.

Table 2-45. Responses to "If yes, about how often do these low workload periods (where breaks could be safely taken) occur during your typical week?" by Position								
Low Workload	CPCs		Developmentals		FLMs		Total	
Periods	%	#	%	#	%	#	%	#
1-2 times a week	8.1%	153	12.5%	46	9.1%	15	8.9%	214
3-4 times a week	23.0%	434	22.6%	83	18.9%	31	22.7%	548
5-6 times a week	22.1%	417	20.7%	76	15.2%	25	21.4%	518
7-8 times a week	10.2%	192	7.4%	27	9.1%	15	9.7%	234
Over 8 times a week	26.2%	495	11.4%	42	22.6%	37	23.7%	574
N/A or don't know	10.4%	196	25.3%	93	25.0%	41	13.6%	330
Total	100.0%	1,887	100.0%	367	100.0%	164	100.0%	2,418

Note: Pearson's Chi Square = 109.3, df 10, p <0.0001.

There were no significant differences between CPCs at different facility types on this question.

CPCs prefer hourly breaks when traffic is busy or workload is high (61.5%) or when providing OJT instruction (44.0%). CPCs prefer breaks every 1 ½ hours when traffic is light or workload is low (40.1%). It can be seen from Table 2-46 that only 35% of CPCs prefer a break after one hour when traffic is light or workload is low, whereas 62% prefer a break after one hour when traffic is busy or workload is high. When providing OJT instruction 44% of respondents prefer a break after one hour.

Table 2-46. Preferred Break Intervals of CPCs in Three Different Conditions						
	When Traffic is Light or Workload is Low		When Traffic is Busy or Workload is High		When Providing OJT Instruction	
Break Interval	%	#	%	#	%	#
After 1/2 hr.	9.6%	221	5.0%	115	1.0%	22
After 1 hr.	34.6%	799	61.5%	1,420	44.0%	1,009
After 1 1/2 hr.	40.1%	927	28.2%	651	35.1%	805
After 2 hrs.	14.7%	339	5.0%	116	6.1%	140
N/A or Don't know	1.0%	24	0.3%	6	13.8%	316
Total	100.0%	2,310	100.0%	2,308	100.0%	2,292

2.2.4.1 Factors Supporting Alertness (or Not)

CPCs and Developmentals said that CPC staffing levels were less than sufficient to support optimal alertness. As shown in Figure 2-18, the number of hours worked and the overall workload were seen as about right. However, traffic complexity and volume were seen as less than sufficient to support optimal alertness, as were the length of time between the breaks, the length of breaks, and rotations of positions. Developmentals felt that there were not enough hours of on-the-job training.

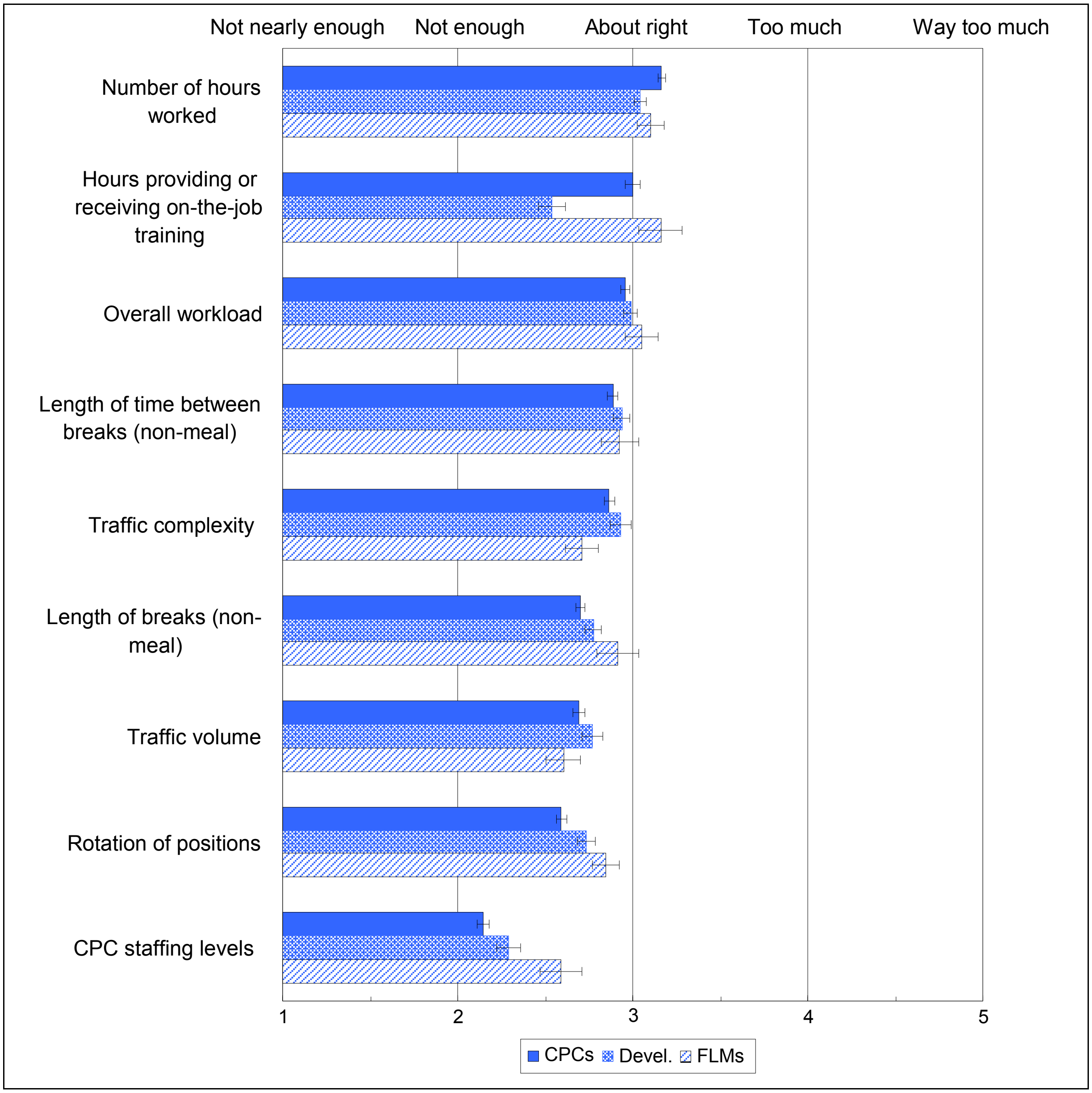

Figure 2-18. Responses by position to "Please indicate the extent to which you feel the following factors are currently at about the right level to support your optimal alertness." n = CPCs 1887 (give OJT) - 2299, Developmentals 425-476, FLMs 170 (give OJT) - 210. Error bars = 95% Confidence Intervals.

Figure 2-19 shows CPC respondents from all facilities, especially TRACONs, rated low levels of staffing as negatively impacting their optimal alertness. CPCs at all facilities rated hours providing on-the-job training and overall workload as about right.

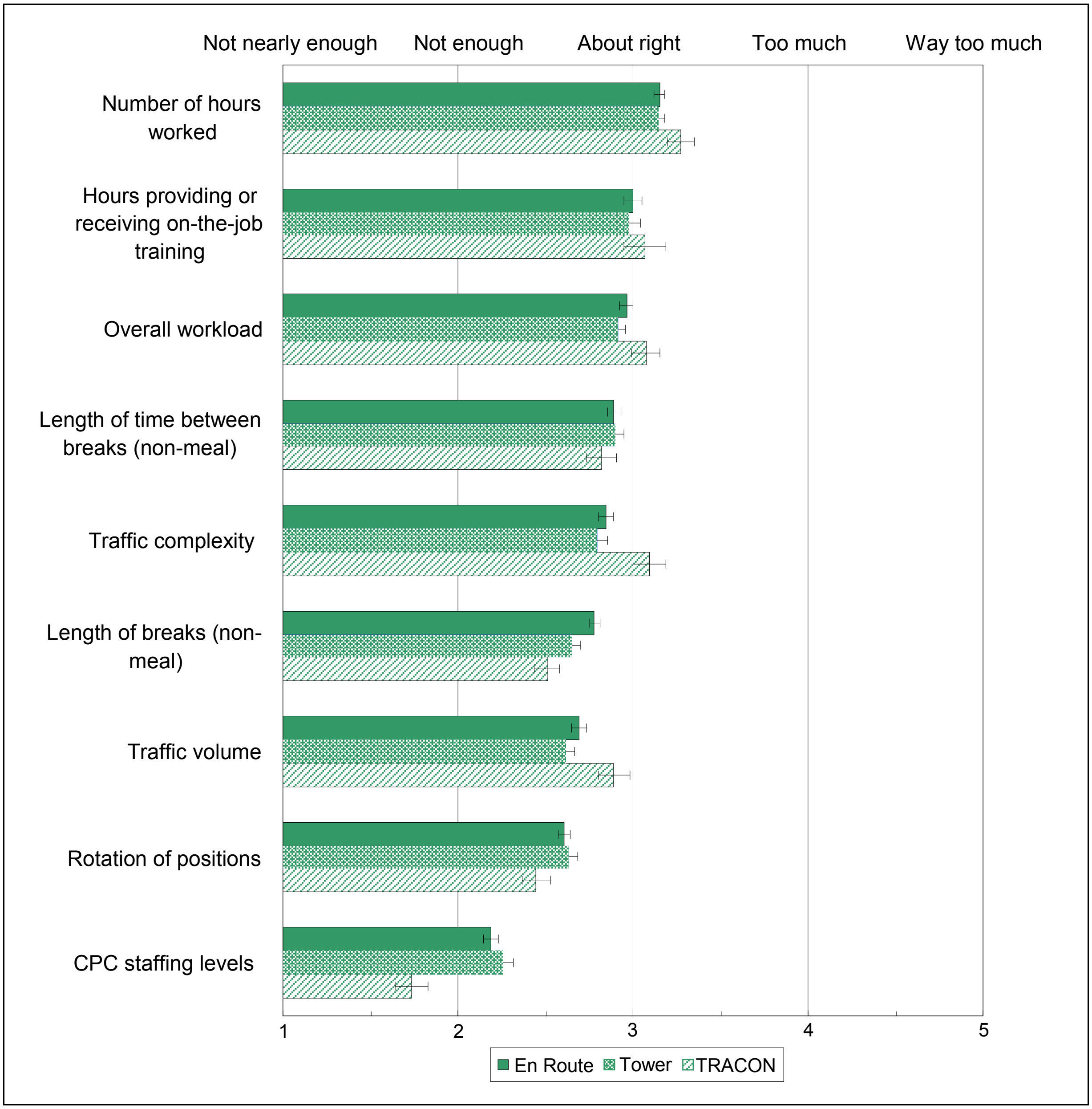

Figure 2-19. CPCs responses by facility to "Please indicate the extent to which you feel the following factors are currently at about the right level to support your optimal alertness". n = En Route 890 (give OJT) - 1159, Tower 705 (give OJT) - 814, TRACON 291(give OJT) - 327. Error bars = 95% Confidence Intervals.

2.2.4.2 Respondents' Comments on Rotations and Breaks

The most frequent comment related to alertness was that positions were staffed unnecessarily when traffic levels were low, as shown in Figure 2-20. This comment was made by 14.4% (49/340) of the 340 respondents (out of 3268) who chose to enter comments in the free text field at the end of this section. These comments support the ratings in Table 2-43, Table 2-44, and Table 2-45, and provide a context for understanding these ratings.

The next most frequent comment, made by 14.1% (48/340) of those who commented, was related to the first: low workload creates difficulties for controllers. The third most frequent comment (13.5%, 46/340) was that air traffic controller workload is highly variable.

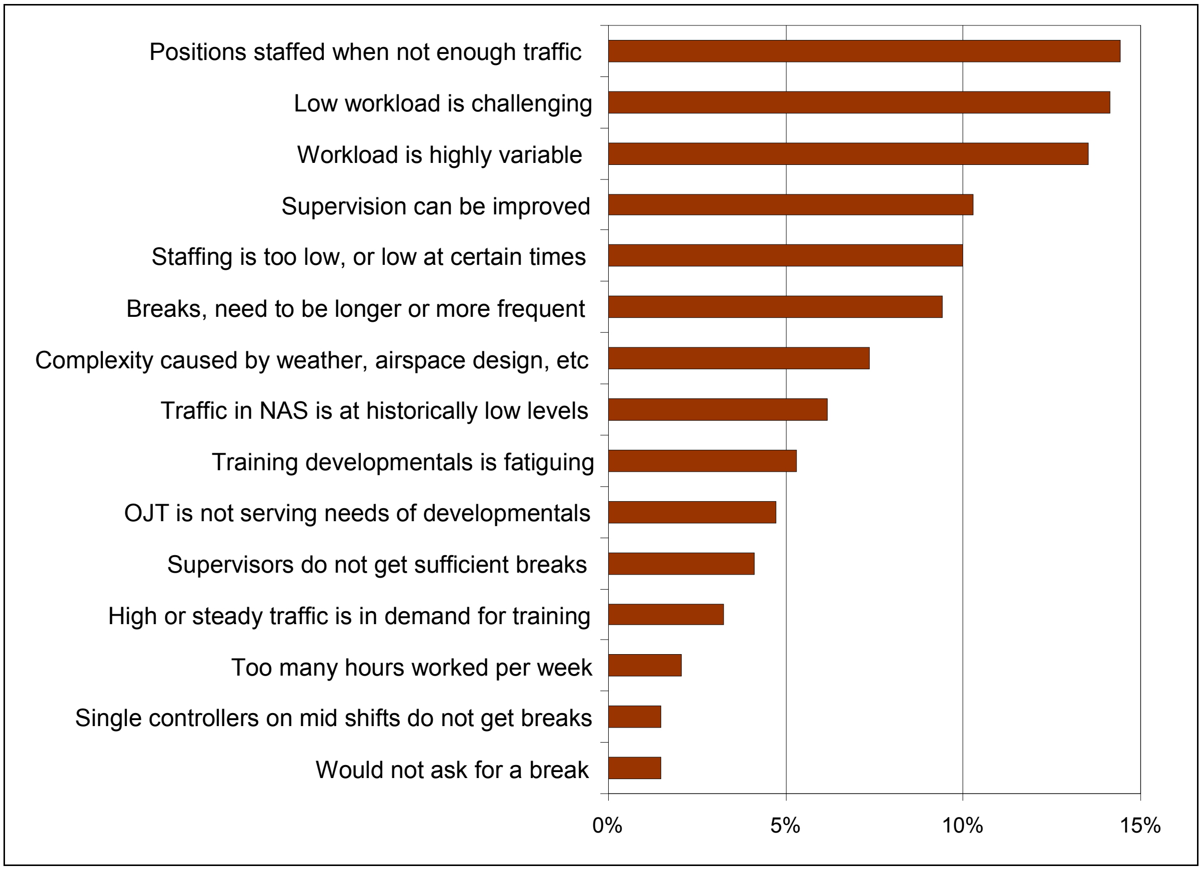

Figure 2-20. Free text comments provided after questions on workload-related fatigue, shown as percentage of those who answered this question (n = 340). Respondents could make multiple comments, hence percentages do not add to 100%.

2.2.5 Stress-Related Fatigue

Figure 2-21 shows that on average, CPCs, Developmentals, and FLMs felt somewhat stressed at work, with CPCs feeling less stressed than the Developmentals or FLMs.

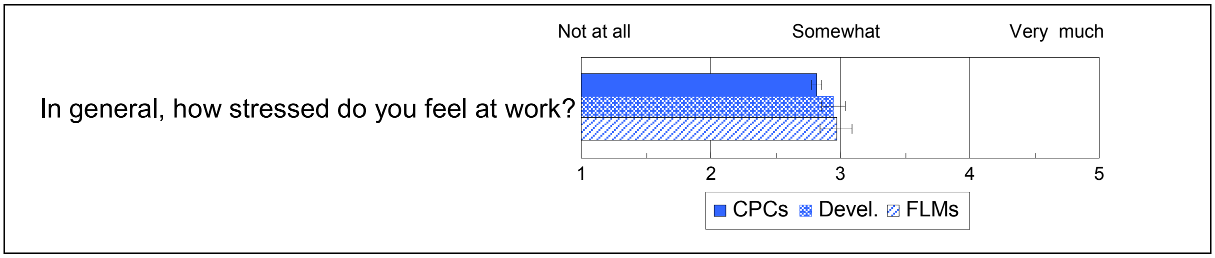

Figure 2-21. Responses to "In general, how stressed do you feel at work?" by position. n = 2297 CPCs, 481 Developmentals, 254 FLMs. Error bars = 95% Confidence Intervals.

Figure 2-22 indicates that CPCs from TRACONs described themselves as more stressed than CPCs from other facilities. This difference was statistically significant.

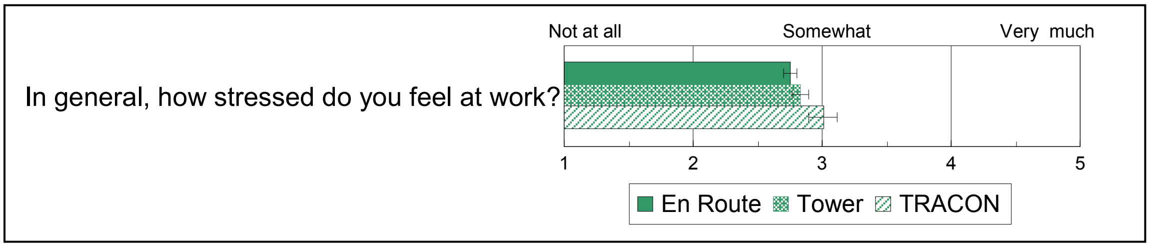

Figure 2-22.CPCs' responses to "In general, how stressed do you feel at work?" by facility. n = 1160 En Route, 809 Tower, 325 TRACON. Error bars = 95% Confidence Intervals.

There were wide discrepancies between sources of stress for CPCs, Developmentals, and FLMs. As shown in Figure 2-23, for all three positions, "upper management decisions" was the primary source of stress, although CPCs saw this as contributing far more to stress than did Developmentals and FLMs. After that, CPCs saw work/life balance, relations with supervisors, and work schedules as sometimes contributing to their stress. Work/life balance and work schedule both figured highly for FLMs as well, although not relations with supervisors. Finally, for Developmentals, responsibility for aviation safety was their second most frequent source of stress, but in general, Developmentals were not as stressed by the typical work-place stressors as were CPCs and FLMs.

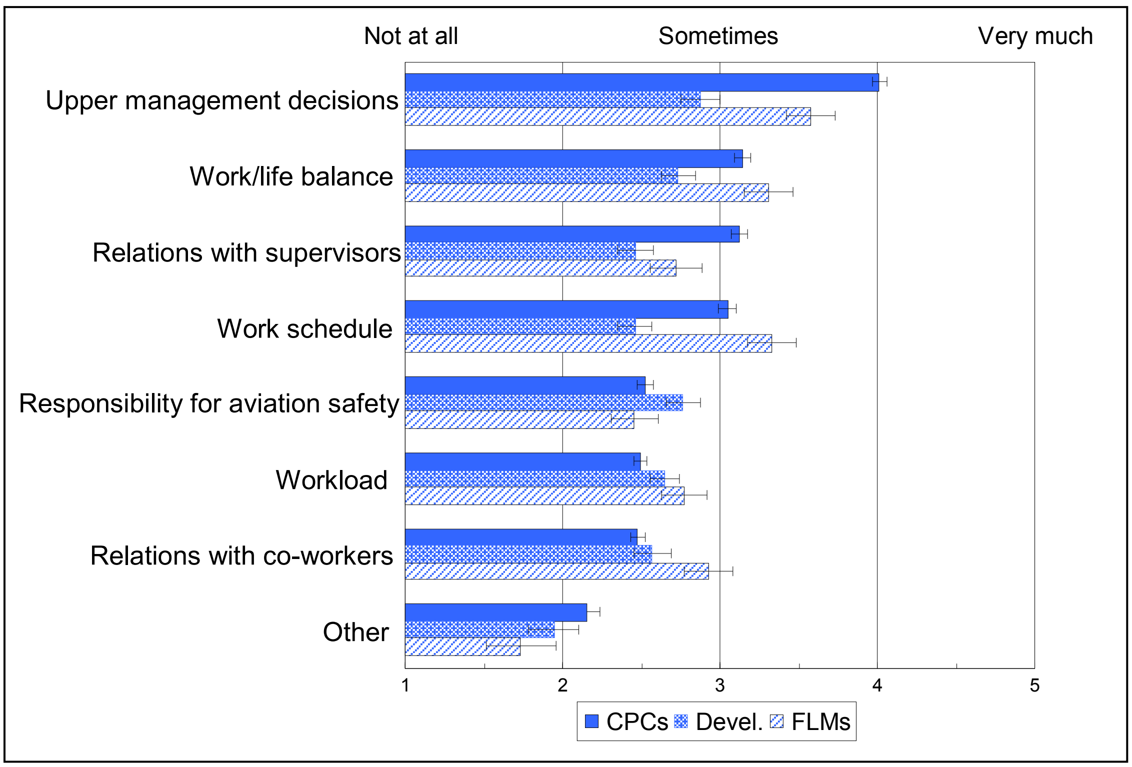

Figure 2-23. Responses by position to "If stressed, to what extent do you feel that the following contribute to your stress?". n = 2211-2219 (Other = 1199) CPCs, 473-475 (Other 306) Developmentals, and 236-9 (117 Other) FLMs. Error bars = 95% Confidence Intervals.

Figure 2-24 shows that workload was seen as a greater source of stress for CPCs from TRACONs than from other facilities; work/life balance and work schedule also were greater sources of stress for CPCs from TRACONS than from En Route centers.

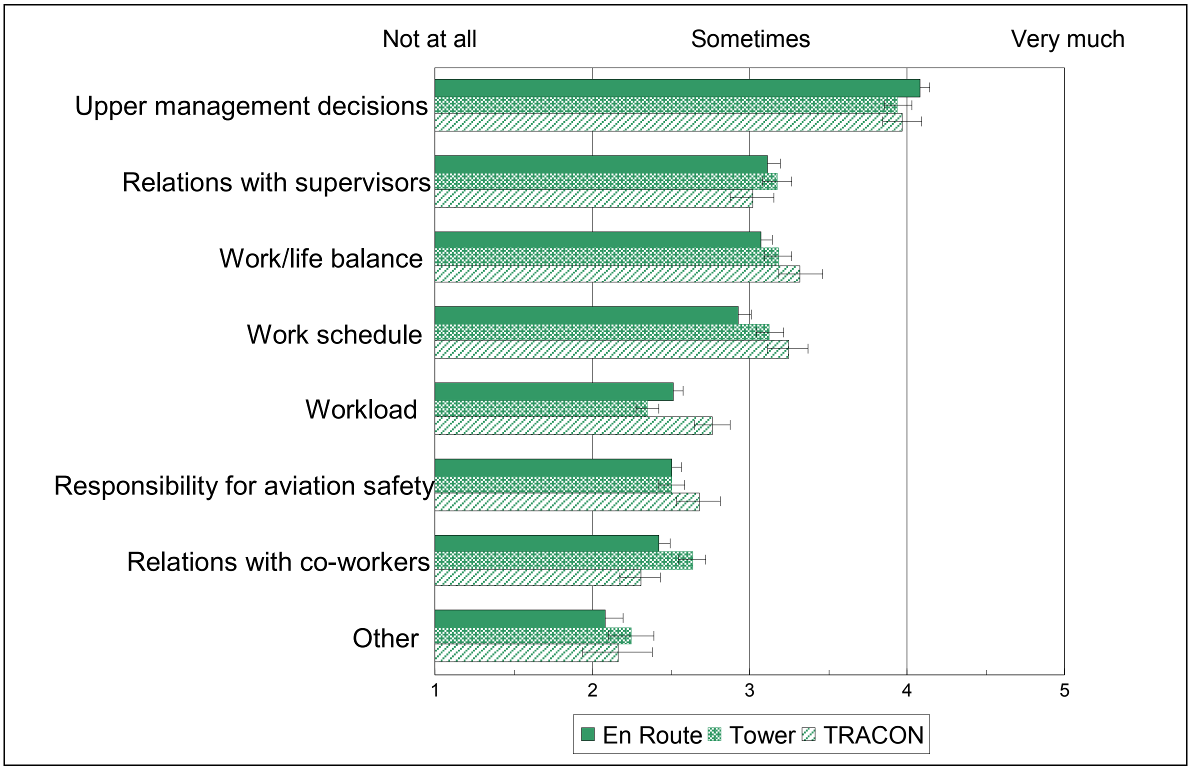

Figure 2-24. CPCs responses by facility type to "If stressed, to what extent do you feel that the following contribute to your stress?". n = 1101-8 (592 Other) En Route, 785-7 (431 Other) Tower, and 321-322 (175 Other) TRACON. Error bars = 95% Confidence Intervals.

2.2.5.1 Commute Times and Second Jobs

Table 2-47 shows that 95% of the respondents drive to work alone. About 4% car pool and 0.2% take public transportation.

Table 2-47. Responses to "How do you usually get to and from work?"

Method of Transportation	Percent	Frequency
Drive alone	95.1%	3,084
Car pool	3.8%	122
Take public transportation	0.2%	8
Other	0.9%	28
Missing		26
Total	100.0%	3,268

Figure 2-25 indicates that the mean one-way commute time range was midway between 16 and 45 minutes (about 30 minutes) and was shorter during low traffic periods such as midnight shifts. This difference was statistically significant.

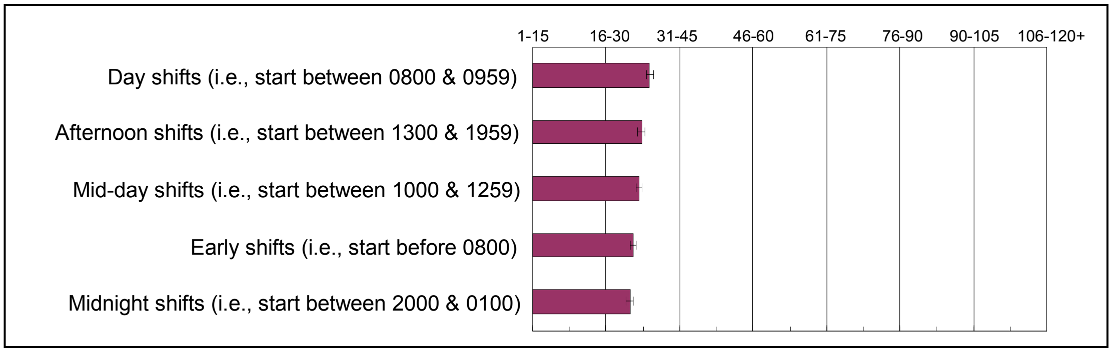

Figure 2-25. Mean range of minutes of the typical one-way commute time to work. n = 2633 (midnights) to 3212 (early). Error bars = 95% Confidence Intervals.

Figure 2-26 shows that CPCs, Developmentals, and FLMs described the mean cost-of-living for the area where they lived as above average.

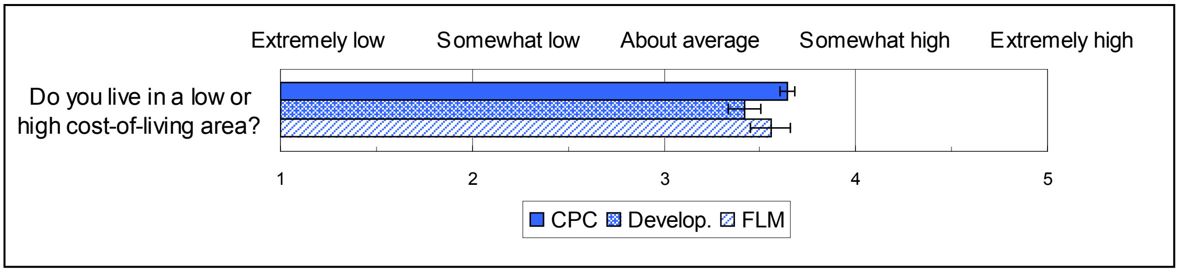

Figure 2-26. Mean estimated cost-of-living for area lived in. n = 2306 CPCs, 488 Developmentals, and 254 FLMs. Error bars = 95% Confidence Intervals.

Figure 2-27 shows that cost of living ratings from TRACON CPCs were higher than cost of living ratings from CPCs at Towers and En Route Centers.

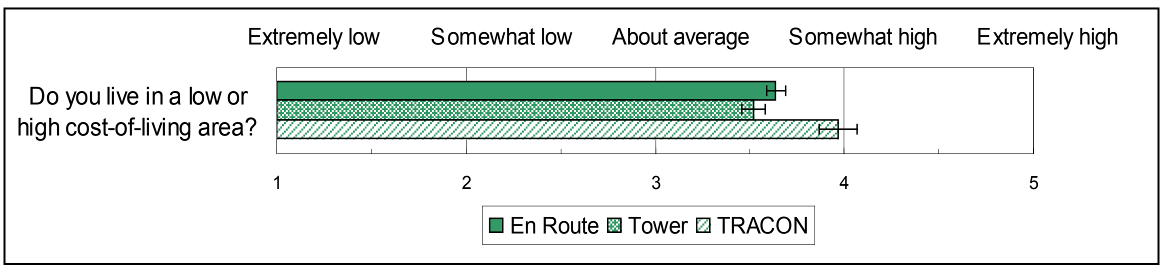

Figure 2-27. CPCs' mean estimated cost-of-living for area lived in. n = 1162 En Route, 814 Tower, and 329 TRACON. Error bars = 95% Confidence Intervals.

7.6% (246/3248) of respondents had a second paid job in addition to their FAA job. There were no statistical differences between positions or facilities in the response to this question. Of those that did have a second paid job, more than half (61.2%) worked under 14 hours per week at their second job as shown in Table 2-48.

Table 2-48. Number of Hours Worked per Week at a Second Paid Job in Addition to an FAA Job		
Hours	Percent	Frequency
Less than 5	15.6%	37
5–9	24.5%	58
10–14	21.1%	50
15–19	16.0%	38
20–24	13.5%	32
25–29	4.2%	10
30+	5.1%	12
Missing or N/A		3,031
Total	100.0%	3,268

2.2.6 Sleep Times and Naps

2.2.6.1 Reported Sleep

Consistent with previous research, sleep time reported by all respondents before an early shift (6.3 hours) was significantly shorter than sleep time before later start times. Figure 2-28 graphically portrays the average sleep times before the various shifts and Table 2-49 provides further details. It can be seen that reported sleep time before an afternoon shift was 7.7 hours, before a mid-day shift was 7.3 hours, before a day shift was 6.7 hours, and before an early shift was 6.3 hours. Reported sleep time was less on an early shift after a very quick turn—5.4 hours—and was 3.1 hours on a quick turn before a midnight shift.

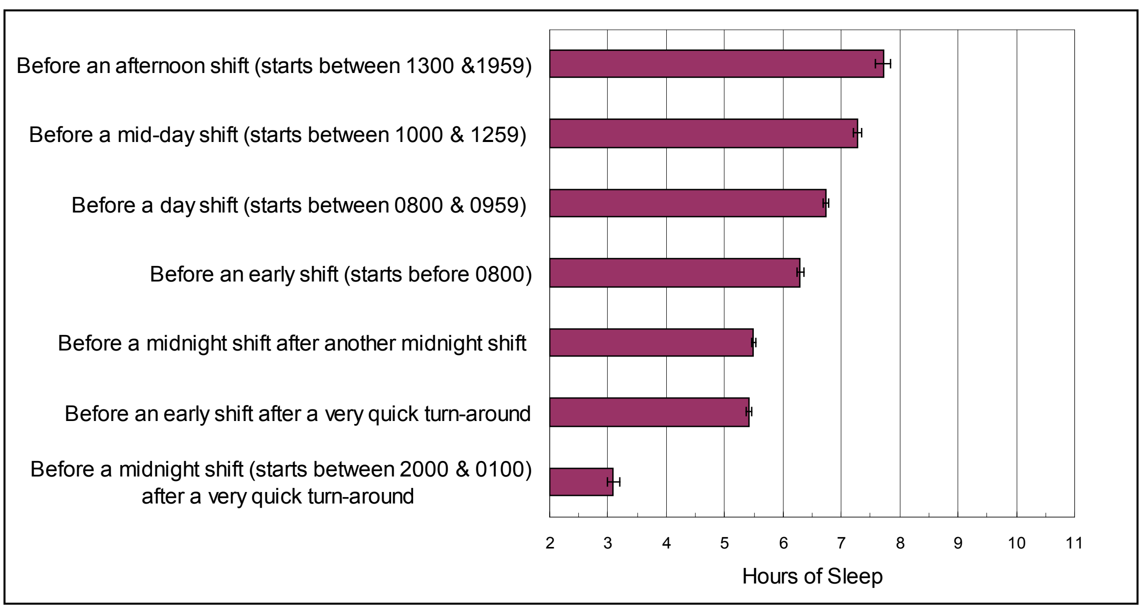

Figure 2-28. Hours of reported sleep by all respondents before various shifts in 2010 survey. n = 1226-3125. Error bars = 95% Confidence Intervals.

Table 2-49. Reported Hours of Sleep before Various Shifts in 2010 Survey by all Respondents		
Shift Type	Mean Hours Slept	n
Before an afternoon shift (starts between 13:00 and19:59)	7.7	2,987
Before a mid-day shift (starts between 10:00 and 12:59)	7.3	2,431
Before a day shift (starts between 08:00 and 09:59)	6.7	2,434
Before an early shift (starts before 08:00)	6.3	3,126
Before a midnight shift after another midnight shift	5.5	1,228
Before an early shift during a very quick turn-around	5.4	2,819
Before a midnight shift (starts between 2000 and 0100) during a very quick turn-around	3.1	1,959

Figure 2-29 indicates that on Regular Days Off (RDOs) after a midnight shift respondents reported sleeping an average of 10.2 hours. This includes an average of 4.8 hours of sleep during the day. On other RDOs, they reported sleeping an average of 8.3 hours. Della Rocco et al. (2000a) in the 1999 survey found an average sleep during the day of 4.3 hours after the midnight shift; the amount in the associated field study was 4.5 hours (Della Rocco & Nesthus, 2005).

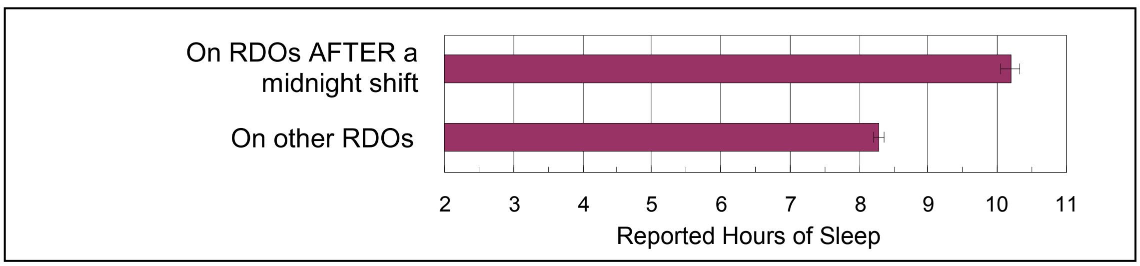

Figure 2-29. Reported hours of sleep on Regular Days Off (RDOs) by all respondents. n = 2112 on RDOs after a midnight shift and 3065 on other RDOs. Error bars = 95% Confidence Intervals.

As shown in Figure 2-30, those with rapidly rotating schedules without midnight shifts (RR) in their bid schedule reported sleeping slightly but statistically significantly more before all shifts than those with midnight shifts (RRM) in their bid schedules.

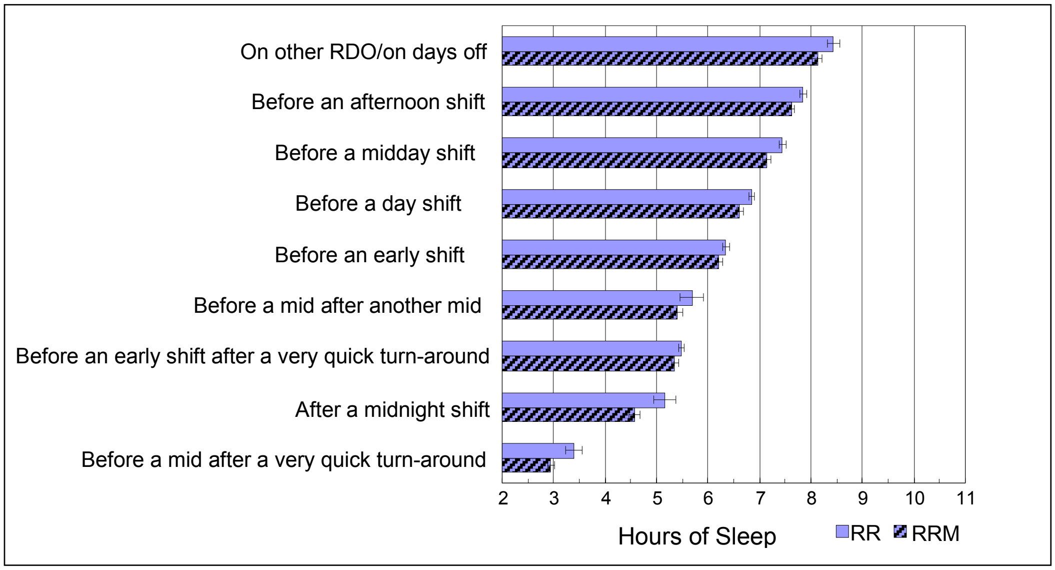

Figure 2-30. Comparison of number of hours of sleep reported by those with rapidly rotating shifts with and without midnights in their bid schedules. (n = 262-1290 RR, 758-1335 RRM.) Error bars = 95% Confidence Intervals.

2.2.6.2 Naps

Most respondents (81.9%) expressed the belief that naps would increase their alertness at work, as shown in Table 2-50. However, 4.4% indicated that that naps would not increase their alertness at work.

Table 2-50. Responses to "Do you feel that naps taken on breaks at work would increase your alertness at work?"

Response	Percent	Frequency
Yes	81.9%	2,653
No	4.4%	144
N/A Don't know	13.6%	441
Total	100.0%	3,238
Missing		30
Total		3,268

Those who felt that naps taken on breaks at work would increase their alertness had a higher mean number of midnight shifts in their 3-week bid schedule than those that who did not. The means were 1.4 midnight shifts versus 0.08 midnight shifts, t = 5.3, df 166.8 (equal variances not assumed), p <0.0001.

Figure 2-31 shows that the largest proportion of respondents would prefer naps during their breaks on the early shifts, followed by the midnight shifts. However, only about half of the respondents had midnight shifts.

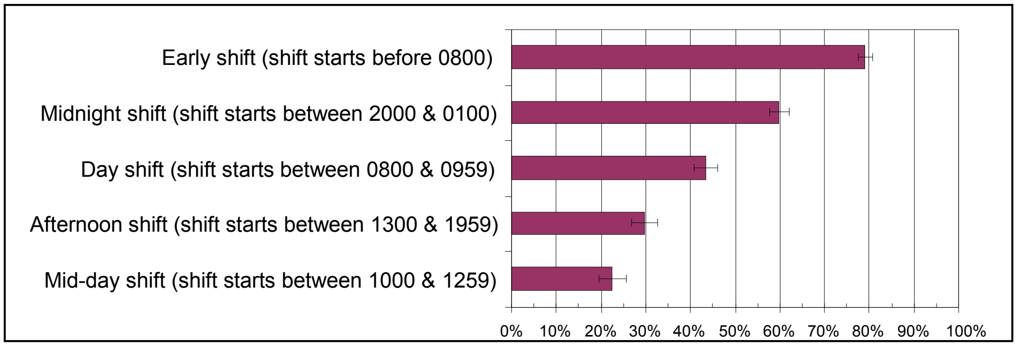

Figure 2-31. Responses to "If yes [naps taken on breaks at work would increase your alertness], on which shifts(s) would naps be of most benefit? (Select all that apply.)". n = 738-2584. Error bars = 95% Confidence Intervals.

Respondents who worked midnight shift schedules felt that naps would provide benefits both on early and on midnight shifts as shown in Figure 2-32.

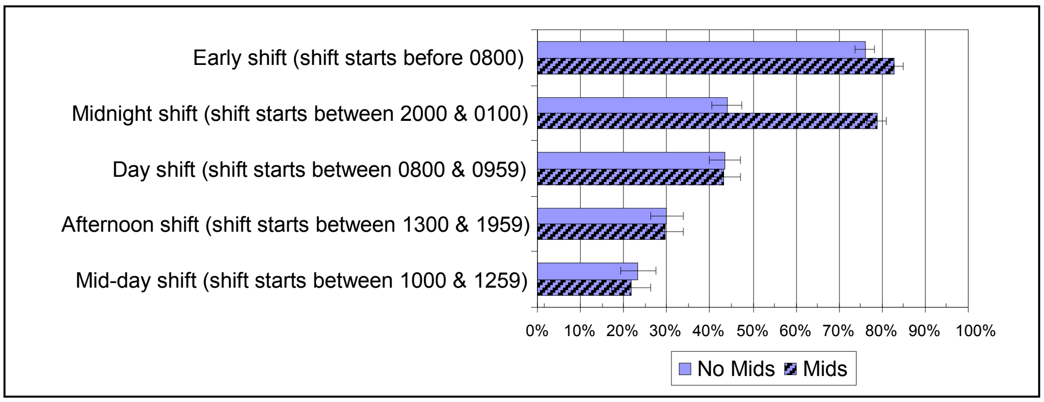

Figure 2-32. Responses of those without and with midnight shifts on their bid schedules to "If yes [naps taken on breaks at work would increase your alertness], on which shifts(s) would naps be of most benefit? (Select all that apply.)". n = 416-1355 for No Mids, and 322-1229 for Mids. Error bars = 95% Confidence Intervals.

2.2.7 Sleep Quality and Shifts

2.2.7.1 Restfulness of Sleep Between Shifts

Figure 2-33 shows that respondents reported feeling least rested after very quick turn-arounds before midnight shifts and before early shifts. This is followed by sleep between successive midnight shifts and between successive early shifts.

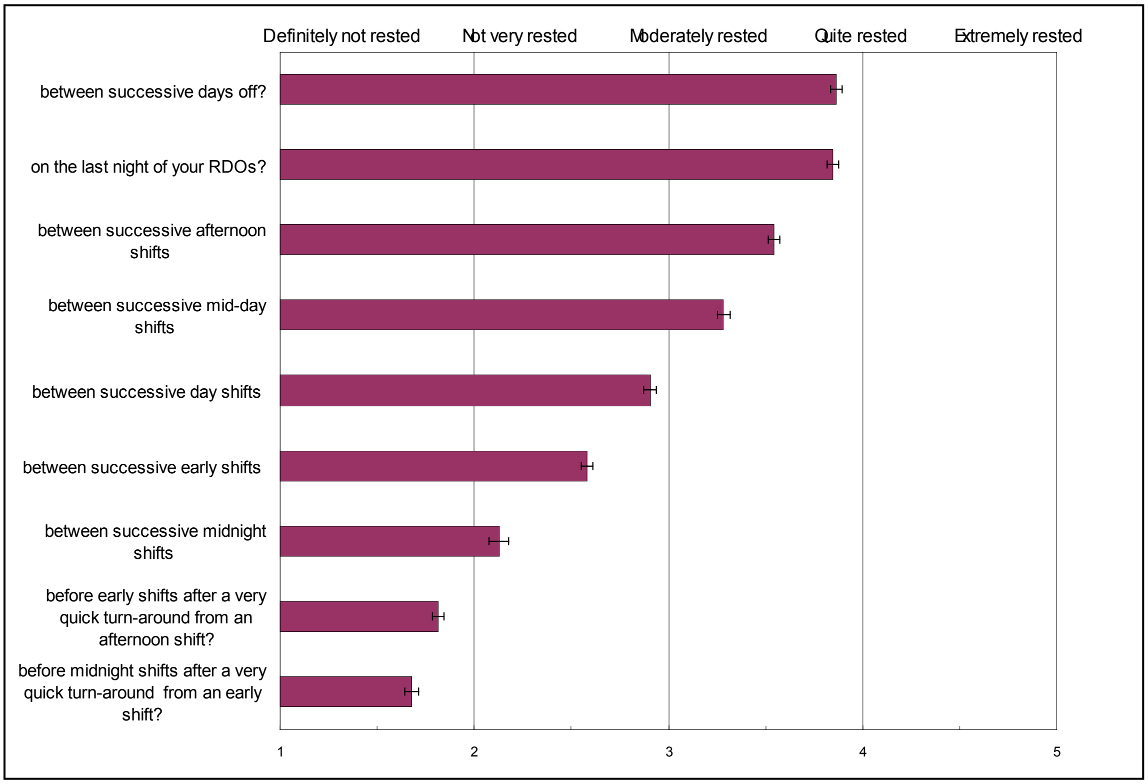

Figure 2-33. Responses to "How rested do you normally feel after sleep..." between various shifts and days off. n = 1813-3186. Error bars = 95% Confidence Intervals.

2.2.7.2 Sleep Patterns During the Work Week

Figure 2-34 indicates that the most frequent sleep problem is awakening in the middle of a sleep period, followed by early awakening and being unable to sleep.

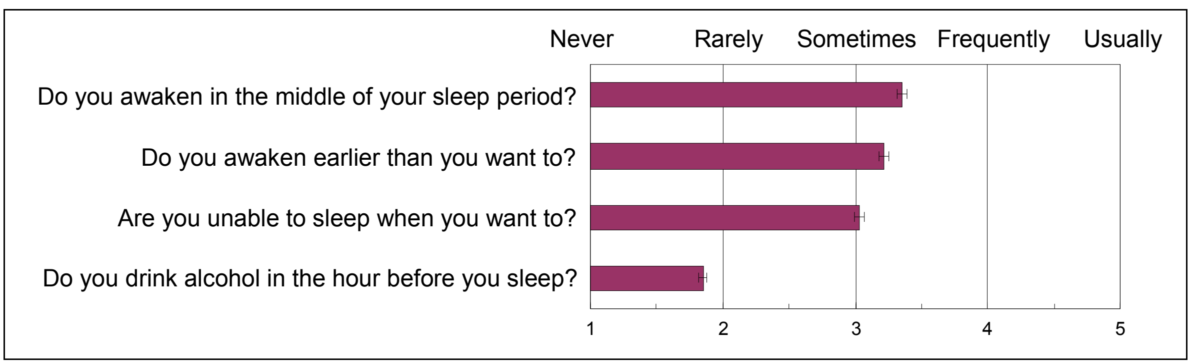

Figure 2-34. Frequency of various sleep patterns and habits. n = 3230-3238. Error bars = 95% Confidence Intervals.

Schedule differences exist regarding awakening in the middle of a sleep period. Awakening occurred more frequently for those on the 6-day Constant schedule and less frequently for those on the 10-hour 4-day schedule than for those on many of the other schedules as shown in Figure 2-35.

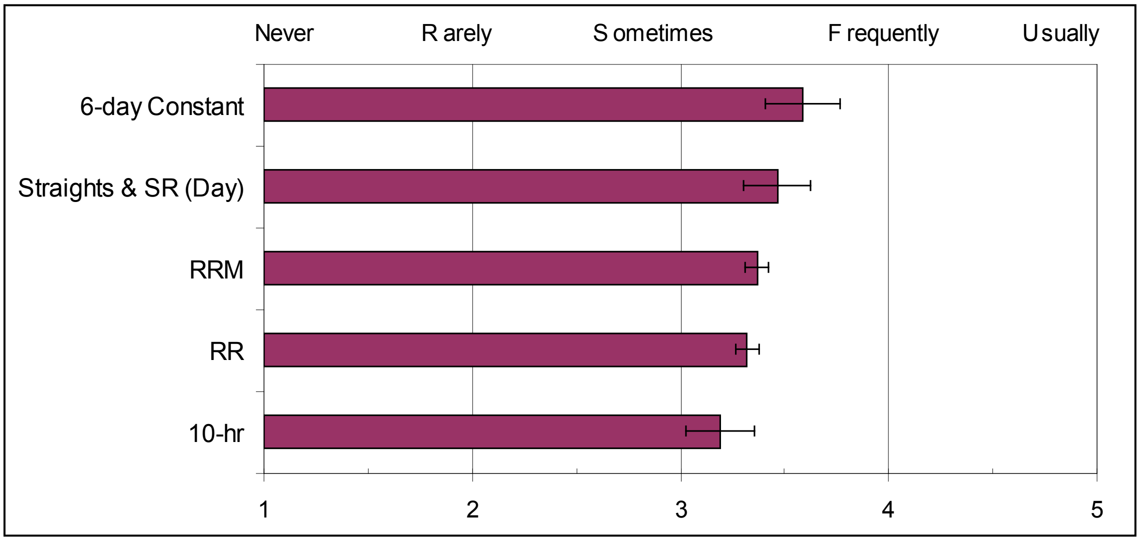

Figure 2-35. Mean responses to "Do you awaken in the middle of your sleep period?" by schedule type. MS 3.6, df 4, p =0.01. The 10-hour 4-day schedule was significantly different from all but the Rapidly Rotating (RR) schedule. The 6-day Constant schedule was significantly different from all but Straights and Slowly Rotating (Day) schedule. Error bars = 95% Confidence Intervals.

Schedule differences exist regarding being unable to sleep when wanted. Being unable to sleep when wanted occurred more frequently for those on the 6-day Constant schedule and less frequently for those on the 10-hour 4-day schedule than for those on many of the other schedules as shown in Figure 2-36. Those with midnight shifts in their bid schedule reported being less likely to be able to sleep when they wanted to than those without midnights. (Means = 3.1 versus 2.9, t = 3.4, df 3228, p <0.001)

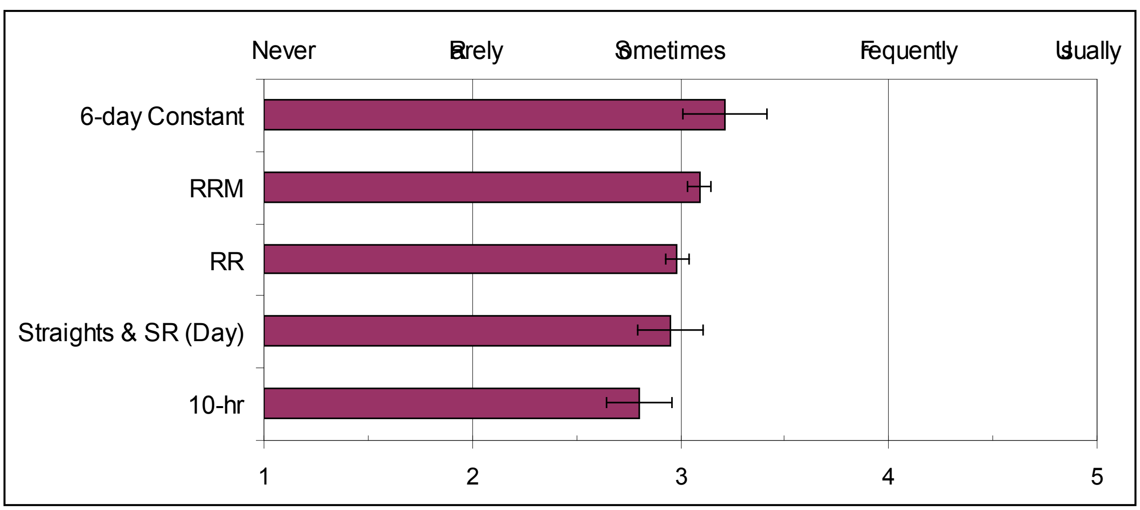

Figure 2-36. Mean responses to "Are you unable to sleep when you want to?" by schedule type. MS 5.4, df 4, F = 4.8, p <0.001. The 10-hour 4-day schedule was significantly different from all but Straights & Slowly Rotating (Day). The 6-day Constant was significantly different from all but the Rapidly Rotating with Midnights schedules. Error bars = 95% Confidence Intervals.

2.2.7.3 Causes of Difficulty in Sleeping

Average consumption of caffeine seems to be moderate, under 3-4 servings a day, as shown in Figure 2-37. It is not known when, relative to a sleep period, the caffeine was consumed.

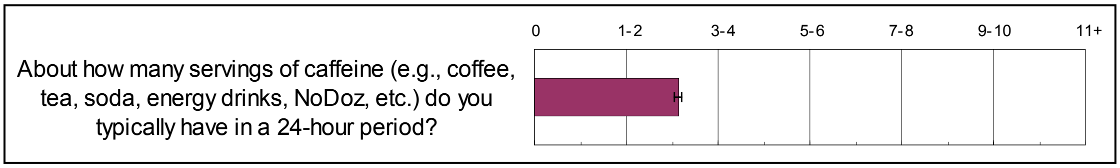

Figure 2-37. Number of caffeine servings typically consumed by respondents in a 24-hour period. (n = 3244). Error bars = 95% Confidence Intervals.

Table 2-51 indicates that while over half of respondents consumed 1-2 or 0 servings of caffeine per 24-hour period, 16% of respondents consume 5 or more servings of caffeine per 24-hour period.

Table 2-51. Proportion and Frequency of Caffeine Servings in a 24-hour Period by All Respondents

Number of Caffeine Servings Per 24 Hour Period	Percent	Frequency
0	13.0%	423
1-2	42.8%	1,389
3-4	28.1%	913
5-6	9.9%	320
7-8	3.7%	121
9-10	1.4%	47
11+	1.0%	31
Total	100.0%	3,244
Missing		24
Total		3,268

As shown in Figure 2-38, the highest proportion of respondents (68%) identified "shift work" as a reason they had trouble sleeping. This was followed by "keyed up, can't relax" by 53% of the respondents. Many of the respondents reported non-schedule impediments to sleep. Examples are disruptions by partners/children/pets and amount of caffeine ingested.

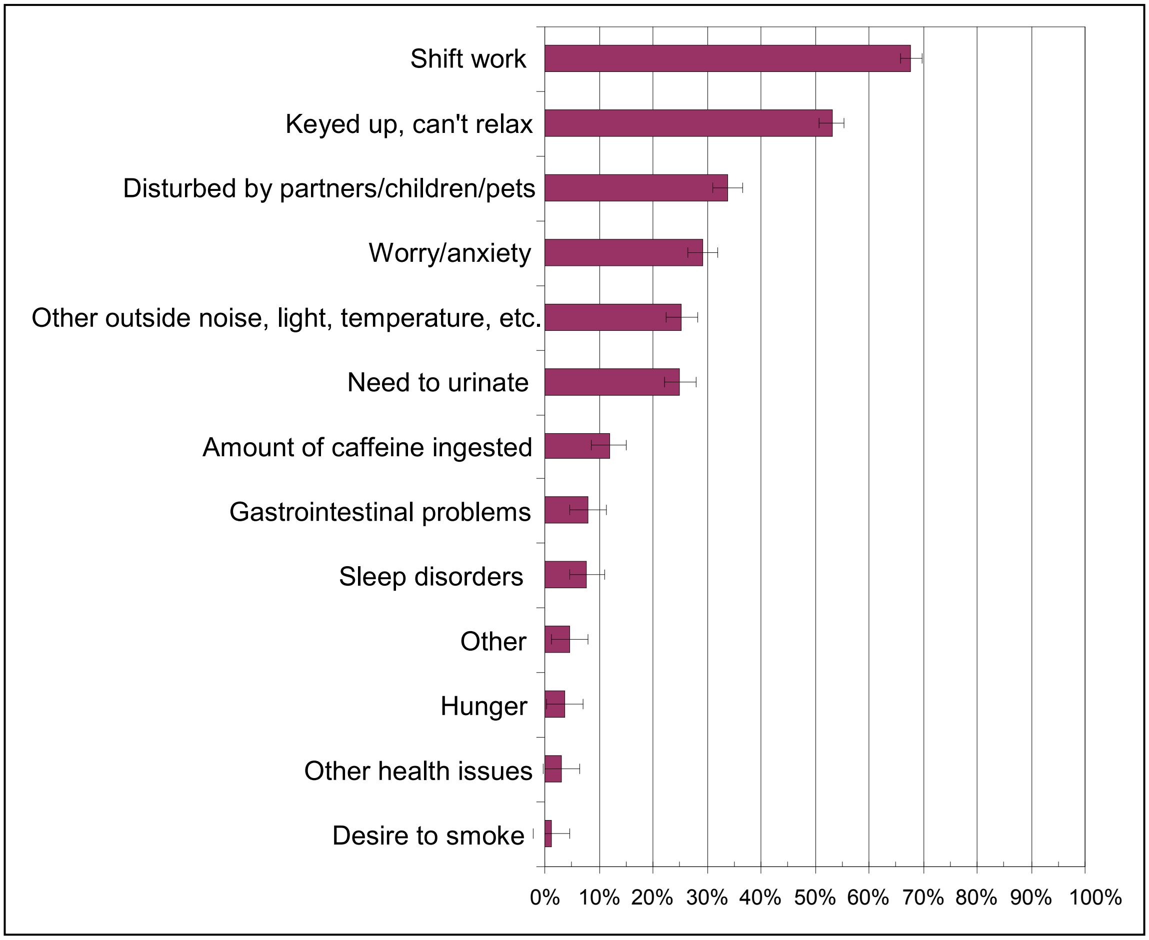

Figure 2-38. Responses to "Do you feel you have trouble sleeping for any of the following reasons? (Check all that apply.)." n = 38-2215 out of 3268. Error bars = 95% Confidence Intervals.

"Sleep disorders" was identified by 7.8% (256/3268) of the respondents. Reported sleep disorders do not increase markedly with age in this sample. Data in Table 2-52 indicates that the proportion of those with self-described sleep disorders rises after age 30 to about 8% and stays fairly constant until ages 51–55, where it reaches 9.9%.

Table 2-52. Proportion of Respondents with a Self-Described Sleep Disorder by Age

Age	Proportion in Each Age Category	Frequency of Self-Described Sleep Disorder	Total in Each Age Category
25 or under	1.8%	3	170
26-30	3.8%	24	627
31-35	7.7%	31	403
36-40	9.3%	24	258
41-45	8.4%	40	479
46-50	9.7%	83	853
51-55	9.9%	39	393
56+	13.8%	8	58
Total	7.8%	252	3,241
Missing		4	27
Total		256	3,268

Of those who reported a self-described sleep disorder, about 41% have rapidly rotating schedules without midnights and a similar proportion have rapidly rotating with midnights, as shown in Table 2-53. About 4% have a 6-day constant schedule.

Table 2-53. Proportion of Respondents with a Self-Described Sleep Disorder by Schedule Type

Schedule	% of those with Self-Described Sleep Disorders	Frequency of Self-Described Sleep Disorder
RR	41.6%	102
RRM	40.8%	100
Straights & SR (Day)	8.2%	20
6-day Constant	3.7%	9
10-hr	5.7%	14
Total	100.0%	245
Missing		11
Total		*256*

If over-the-counter or prescribed medications to aid sleep were allowed, about a quarter of the respondents indicated they would take them. Another quarter was undecided and half would not take them, as shown in Table 2-54.

Table 2-54. Proportion and Number of Respondents Who Would Take Over-the-Counter

or Prescribed Medications for Sleep		
Response	Percent	Frequency
Yes	24.4%	796
No	50.0%	1,633
Don't know	24.9%	815
Missing	0.7%	24
Total	100.0%	3,268

2.2.7.4 Hours of Sleep Needed

Figure 2-39 shows that the average amount of sleep respondents believed they needed in a 24-hour period, irrespective of shifts, was around 7-8 hours.

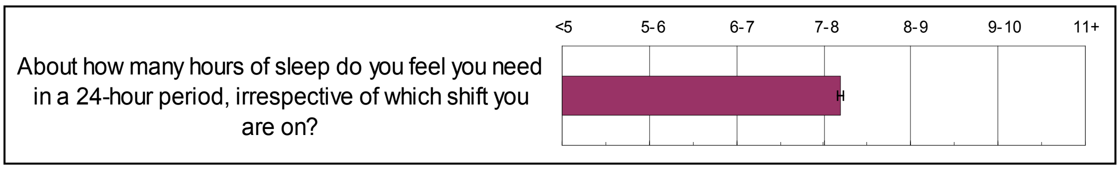

Figure 2-39. Average responses to "About how many hours of sleep do you feel you need in a 24-hour period, irrespective of which shift you are on?" n = 3251. Error bars = 95% Confidence Intervals.

2.2.8 Alertness

2.2.8.1 Alertness at the Beginning and End of Shifts

Respondents reported being least mentally sharp at the beginning of early shifts after a very quick turn-around. Respondents also reported being less alert at the beginning of a midnight shift after a very quick turn-around. Figure 2-40 shows how "mentally sharp (e.g., alertness, memory)" Respondents described themselves as being at the beginning of the various shift types.

At the end of the shifts, respondents were least mentally sharp on midnight shifts, particularly midnight shifts after a very quick turn-around, as shown in Figure 2-41. These are the lowest alertness ratings received on any of the measures, including time-on-shift without a break under varying workloads.

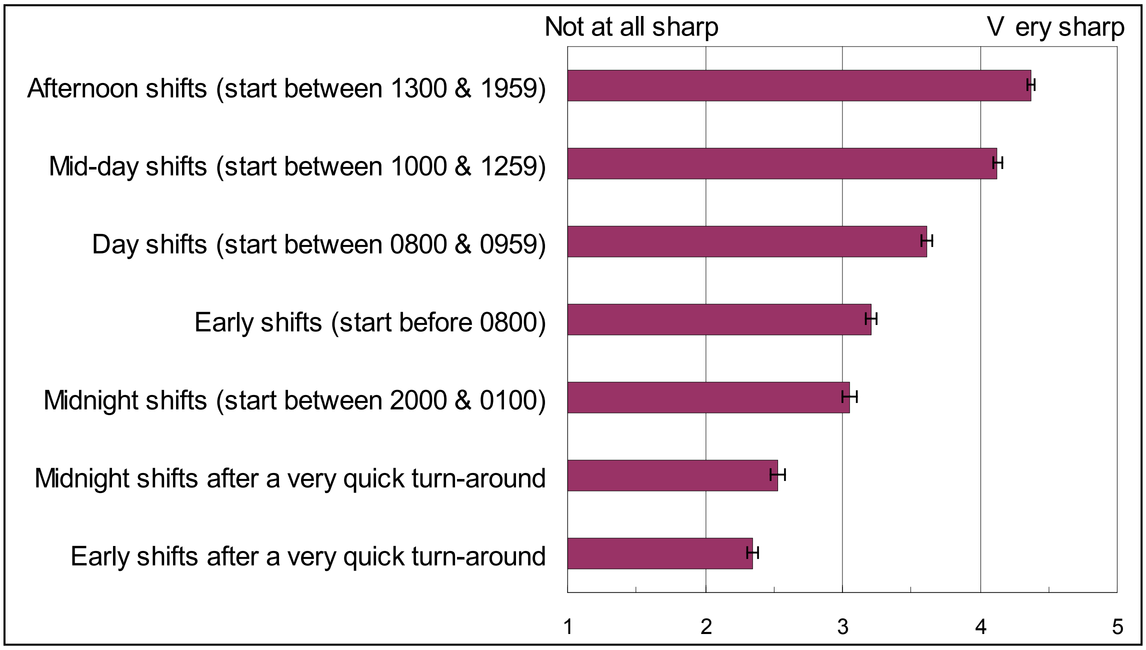

Figure 2-40. Alterness at the beginning of shifts. ns = 2155-3169. Error bars = 95% Confidence Intervals.

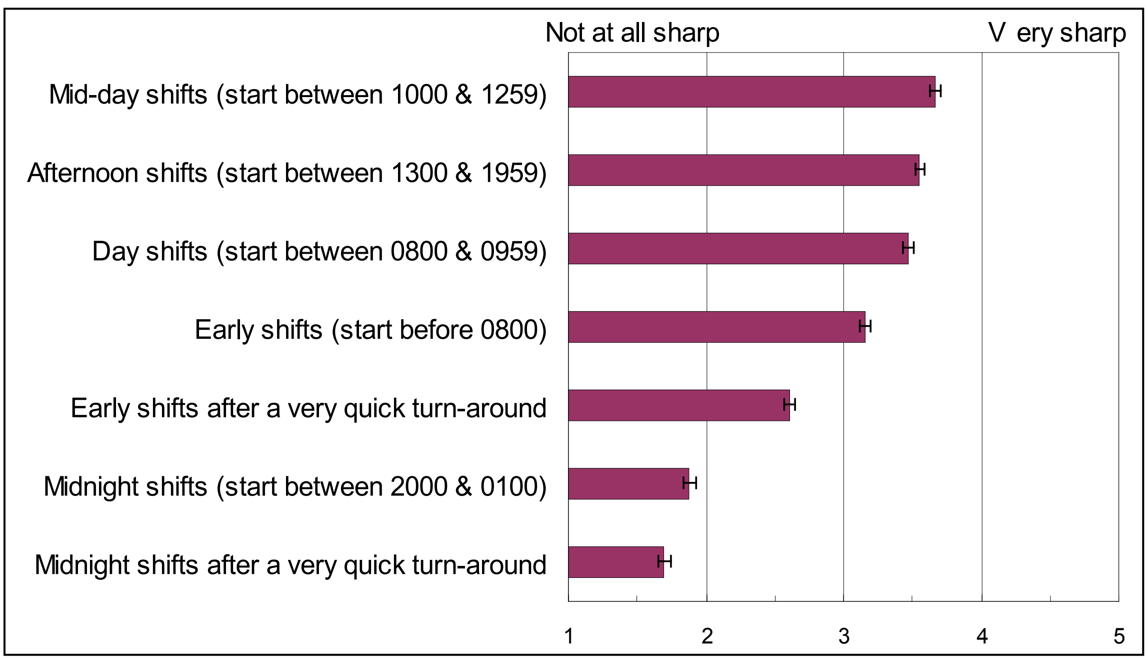

Figure 2-41. Alertness at the end of shifts.ns = 2296-3064. Error bars = 95% Confidence Intervals.

2.2.8.2 Alertness After Periods of Light and Heavy Traffic

Figure 2-42 shows that during most time on position periods from ½ to 1½ hours, respondents felt less sharp after light traffic than a heavy push.

Comparing the results in Figure 2-41 with those in Figure 2-42, it can be seen that midnight shifts have more of an adverse impact on alertness (rated sharpness) than time on duty without a break, regardless of the traffic level.

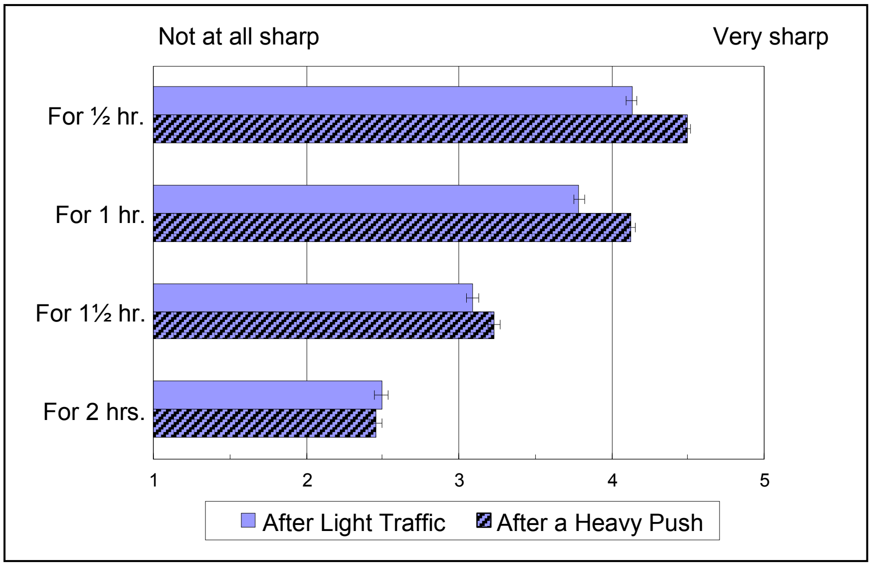

Figure 2-42. Alertness after light and heavy traffic after varying time periods. ns = 3067-3100 light traffic, 3079-3085 heavy traffic. Error bars = 95% Confidence Intervals.

2.2.8.3 "About to 'Doze Off'" During Work Duties

When respondents were asked if they had caught themselves "about to 'doze off'" during work duties in the last year, 61.2% replied "Yes." (n = 1967 "Yes," 1248 "No," Missing 53, Total 3268.) Developmentals were least likely to respond in the affirmative (35%, 169/481). However, Developmentals typically do not work midnight shifts. FLMs and CPCs responded affirmatively at higher rates than Developmentals: 64% (160/250) and 66% (1515/2286), respectively (Pearson's Chi-Square = 163, df 2, p <0.0001). Those with midnight shifts were much more likely to reply "yes" to this question (71.1%, 1043/1467) than those without midnight shifts (52.9%, 924/1748) (Pearson's Chi-Square = 111.7, df 1, p <0.001).

As found in previous results, CPCs from TRACONs had the highest rate of catching themselves "about to 'doze off'" during work duties in the last year at 74.5% (240/322). In Tower facilities, the rate was 68.2% (552/809) followed by En Route at 62.6% (722/1154). (Pearson's Chi-Square = 18.3, df 2, p <0.0001.)

Table 2-55 shows that 71% of those with 6-day constant and 70% of those with rapid rotating with midnight schedules reported catching themselves "about to 'doze off'" during work duties in the last year.

Table 2-55. Proportion of Respondents with Various Schedule Types who Reported Catching Themselves "About to 'Doze Off'" during Work Duties in the Last Year

Schedule	%	N	Total
6-day Constant	71.1%	81	114
RRM	70.4%	946	1,343
Straights & SR (Days)	60.0%	99	165
10-hr. 4-day	57.2%	95	166
RR	51.4%	674	1,312
Average/Total	61.1%	1,895	3,100
Missing			168
Total			*3,268*

Note: Pearson's Chi-Square = 107.43, df 4, p <0.0001.

Figure 2-43 indicates that of those who reported catching themselves as "about to 'doze off'" during work duties in the past year, the shift where this most frequently occurred was on midnight shifts after a very quick turn-around. This was followed second by regular midnight shifts and third by early shifts after very quick turn-arounds.

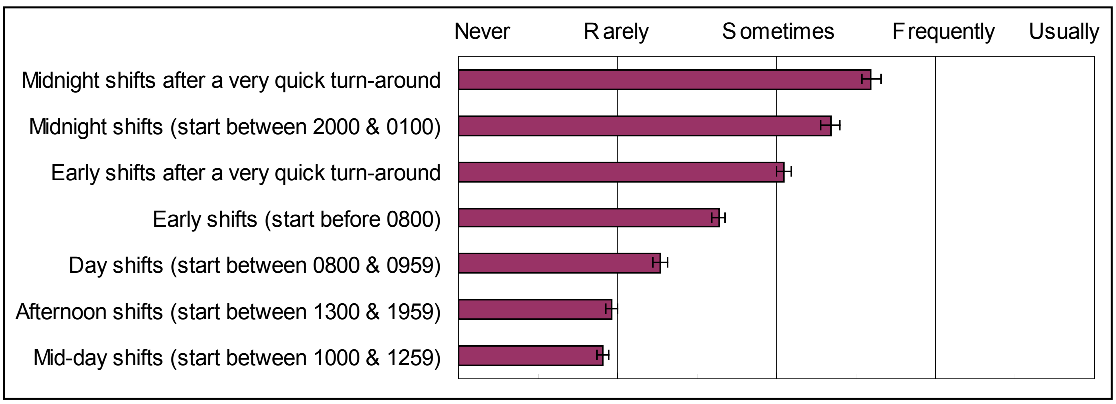

Figure 2-43. Shifts on which that respondents were most likely to report "about to 'doze off'" on, if any. ns = 1499- 2033. Error bars = 95% Confidence Intervals.

2.2.8.4 "About to 'Doze Off'" During Breaks After Light and Heavy Traffic

Respondents rated the frequency of catching themselves "about to 'doze off'" on a break after light traffic as higher than after a heavy push as shown in Figure 2-44.

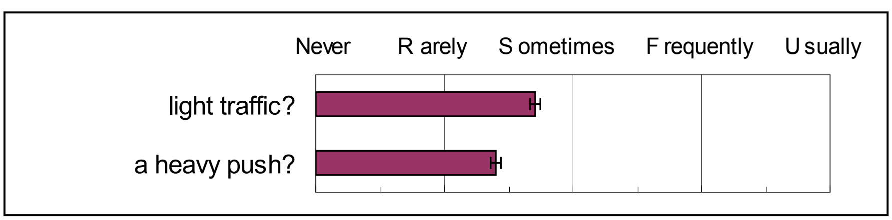

Figure 2-44. Mean responses to "In the last year, have you caught yourself "about to 'doze off'" on a break after..." [light traffic] [a heavy push]. n = 2984 light traffic, 2986 a heavy push. Error bars = 95% Confidence Intervals.

2.2.8.5 Fatigue Scales

2.2.8.5.1 Modified Brief Fatigue Inventory

The mean score on the Modified Brief Fatigue Inventory was 18.7. (n = 3185, SE = 0.106, SD = 5.98.) **Figure 2-45 shows that Developmentals scored significantly lower on the Modified BFI than FLMs and CPCs.**

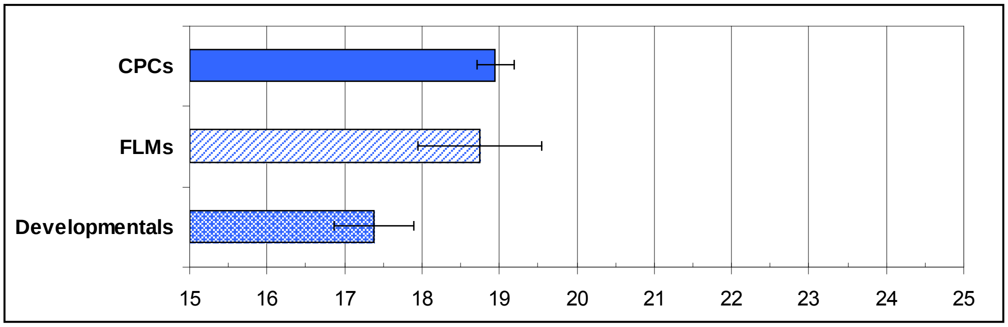

Figure 2-45. Modified BFI by position. n = 2263 CPCs, 249 FLMs, 481 Developmentals. Error bars = 95% Confidence Intervals.

Figure 2-46 indicates that CPCs from TRACONs scored significantly higher than those from other facilities on the Modified Brief Fatigue Inventory.

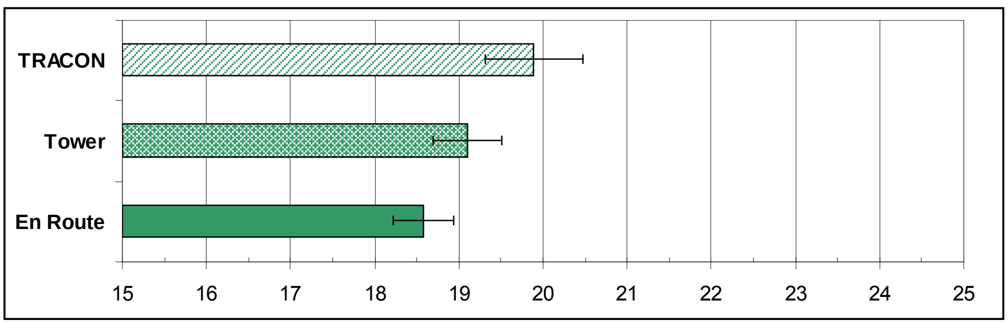

Figure 2-46. CPC responses to Brief Fatigue Inventory (Modified) by Facility Type. TRACON significantly different from En Route at p <0.0001 and from Tower at p = 0.045. ns = 319 TRACON, 800 Tower, 1143 En Route. Error bars = 95% Confidence Intervals.

Figure 2-47 shows that the schedules that contributed the most to fatigue on the MBFI were the 6-day constant and the rapidly rotating with midnights. The three schedules that contributed the least to fatigue were the 10-hour, the rapidly rotating (no midnights), and the straights and slowly rotating days.

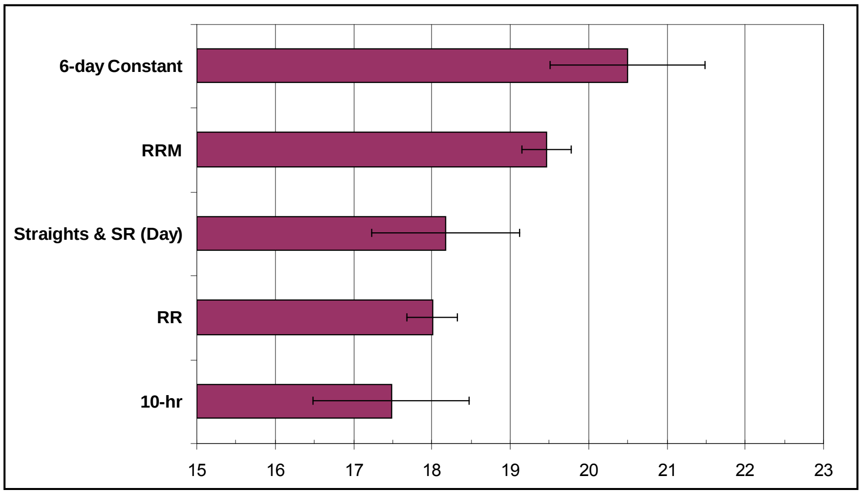

Figure 2-47. Mean ratings of those with five schedule types on the Brief Fatigue Inventory. n = 3070. Error bars = 95% Confidence Intervals.

2.2.8.5.2 Chronic Fatigue Scale

The mean Chronic Fatigue Scale score obtained from the respondents was 26.61 (n=3126, SD=8.31). Figure 2-48 indicates that developmentals have the lowest scores on the Chronic Fatigue Scale.

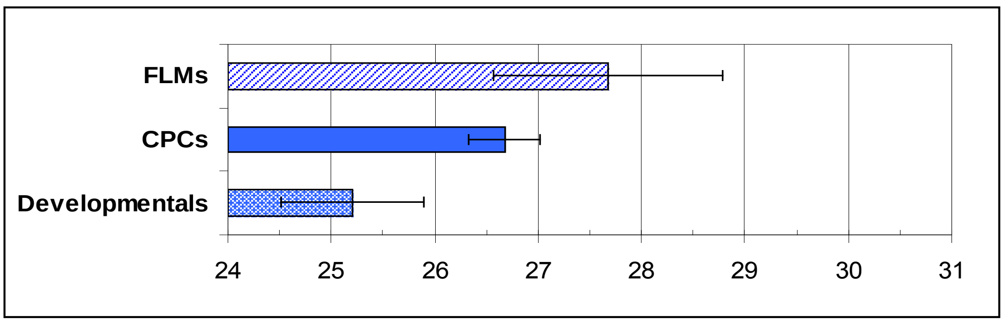

Figure 2-48. Chronic Fatigue Scale by position. n = 240 FLMs, 2233 CPCs, 459 Developmentals. Error bars = 95% Confidence Intervals.

CPC ratings on the Chronic Fatigue Scale in Figure 2-49 show that respondents from TRACONs reported the highest chronic fatigue with a mean of over 28.

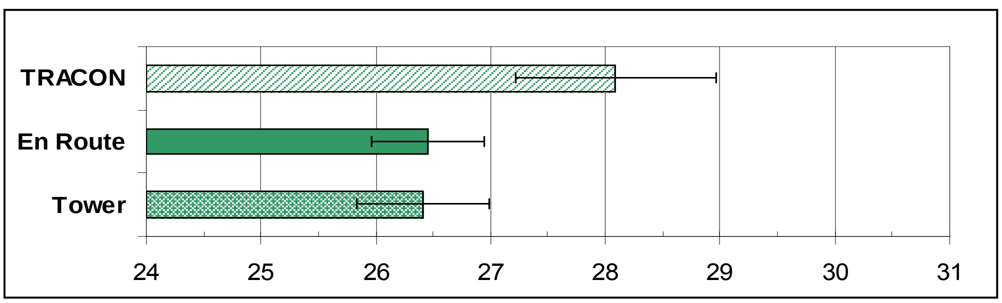

Figure 2-49. Chronic Fatigue Scale by CPC's facility type. ns = 320 TRACON, 1119 En Route, 793 Tower. Error bars = 95% Confidence Intervals.

Figure 2-50 shows the schedules that contributed the most to fatigue as measured by the Chronic Fatigue Scale.

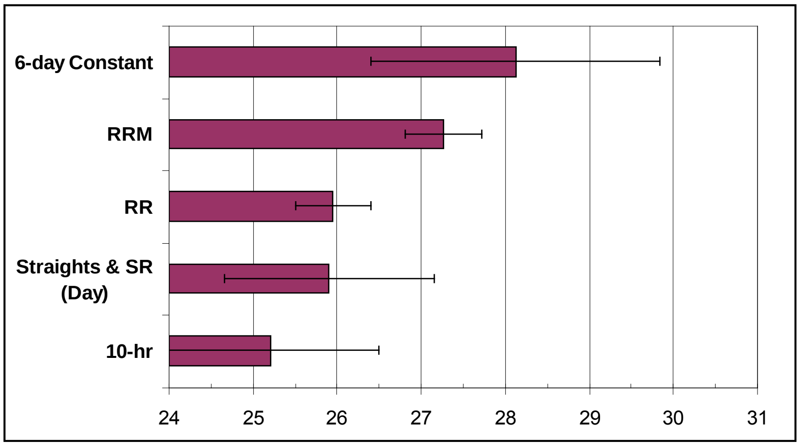

Figure 2-50. Mean ratings of those with five schedule types on the Chronic Fatigue Scale. n = 3085. Error bars = 95% Confidence Intervals.

2.2.8.5.3 Epworth Sleepiness Scale

The mean score on the Epworth Sleepiness Scale was 8.6 (n = 3129, SE = 0.08, SD = 4.45), which would be scored as "high average." The standard ratings are 1–6 = sufficient sleep, 7–8 = average sleep, and 9 and up "in need of medical attention."

As can be seen in Figure 2-51, FLMs were significantly more sleepy than the others on the Epworth Sleepiness Scale. There was no significant difference in sleepiness between CPCs by facility types.

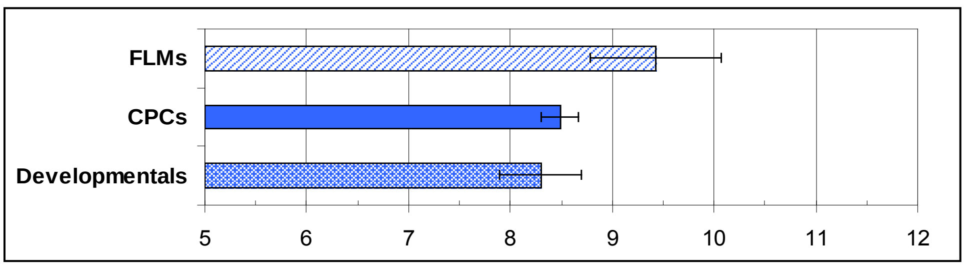

Figure 2-51. Mean score on Epworth Sleepiness Scale by Position. n = 243 FLMs, 2227 CPCs, 469 Developmentals. Error bars = 95% Confidence Intervals.

Those working the 6-day schedule experienced the most sleepiness as measured by the Epworth Sleepiness Scale and those working 10-hour 4-day schedules experienced the least sleepiness as shown in Figure 2-52.

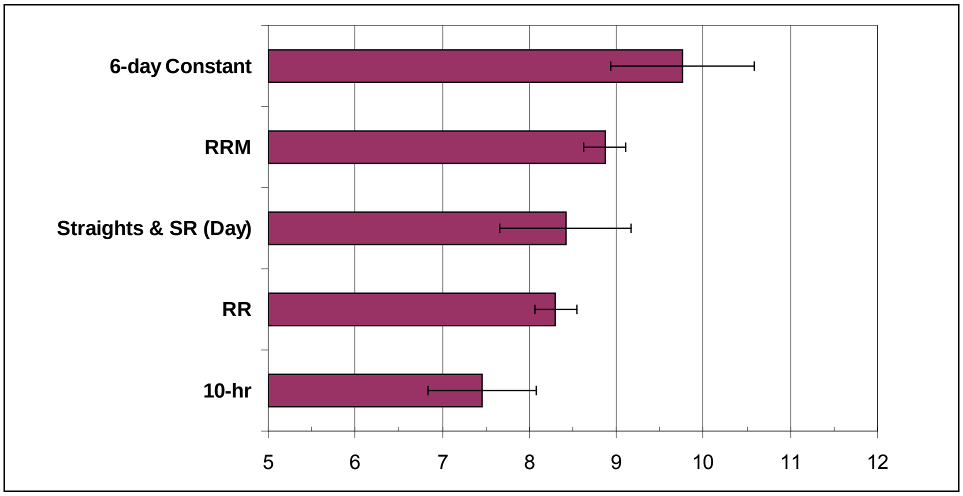

Figure 2-52. Mean ratings of respondents those controllers with five schedule types on the Epworth Sleepiness Scale. (All 6-day differences significant at p <0.05; all 10-day differences significant at p ≤0.05). n = 3018. Error bars = 95% Confidence Intervals.

2.2.8.6 Working a Midnight Shift or Not: Effects on Fatigue Scales

Working one or more midnight shifts on the bid schedule was significantly associated with fatigue on all three fatigue scales used in the survey. The means on the Epworth were 8.1 for no midnights and 8.8 with midnights, t = 3.7, df 2149 (equal variances not assumed), p <0.0001; on the Brief Fatigue Inventory 18.3 vs. 19.4, t = 2261, p <0.0001; on the Chronic Fatigue Scale 26.0 vs. 27.2, df 2139 (equal variances not assumed), p <0.001.

2.2.8.7 Alertness Indicators

2.2.8.7.1 Driving Experiences

Respondents were asked "In the last year, how often have you had a momentary lapse of attention while you were driving to or from" various shifts. A second question substituted "did you fall asleep (for a few seconds)" for "momentary lapse of attention." A 4-point rating scale of Never, Sometimes, Frequently, and Always, was provided along with a not applicable (N/A) option.

In the current survey, momentary lapses of attention while driving to or from work in the past year were reported as occurring most frequently with midnight shifts, as shown in Table 2-56. Of those responding to this question, 66% reported having had a momentary lapse of attention at least "sometimes" while driving to or from midnight shifts in the last year. Following in descending order were shifts involving OJT (61.4%), early shifts (60.4%), a busy shift (59.6%), and a light shift (52.6%).

Table 2-56. Responses to "In the last year, how often have you had a momentary lapse of attention while you were driving to or from [various types of shifts]?" [7]

Driving To or From	% Who Reported Having a Lapse of Attention at Least Sometimes (of Those Who Responded)	# Who Reported Having a Lapse of Attention at Least Sometimes	Total n Responding	% of Whole Sample (n = 3268)
Midnight shifts (i.e., shift starts between 20:00 & 01:00)	66.0%	1,508	2,285	46.1%
A shift giving or receiving OJT	61.4%	1,493	2,432	45.7%
Early shifts (i.e., shift starts before 08:00)	60.4%	1,849	3,061	56.6%
A busy shift	59.6%	1,713	2,875	52.4%
A light shift	52.6%	1,497	2,846	45.8%
Day shifts (i.e., shift starts between 08:00 and 09:59)	43.3%	1,172	2,707	35.9%
Afternoon shifts (i.e. shift starts between 13:00 and 19:59)	34.6%	1,033	2,989	31.6%
Mid-day shifts (i.e., shift starts between 10:00 and 12:59)	28.9%	784	2,717	24.0%

Falling asleep (for a few seconds) while driving to or from work was also reported as occurring most frequently with midnight shifts. Of those responding to this question, 28% (689/2460) reported that they had fallen asleep for a few seconds at least “sometimes” in the past year, as shown in Table 2-57. Following in descending order were a light shift (18.8%), a busy shift (17.9%), a shift involving OJT (16.8%), and early shifts (16.6%). Thirty-three percent (489/1486) of those who worked midnight shifts on a regular basis reported falling asleep for a few seconds to and from midnight shifts.

7 If the respondent’s most recent shift was affecting their driving ability, the effect would occur when driving from work rather than to work. However, the wording of the question was left unchanged from that used in the 1999 survey to enable comparison.

Table 2-57. Responses to "In the last year, how often did you fall asleep (for a few seconds) while you were driving to or from [the following various types of shifts]?"

Driving To or From	% Who Reported Falling Asleep at Least Sometimes (of Those Who Responded to Question)	# Who Reported Falling Asleep at Least Sometimes	Total N Responding	% of Whole Sample (n = 3268)
Midnight shifts (i.e., shift starts between 20:00 and 01:00)	28.0%	689	2,460	21.1%
A light shift	18.8%	519	2,761	15.9%
A busy shift	17.9%	496	2,771	15.2%
A shift giving or receiving OJT	16.8%	418	2,494	12.8%
Early shifts (i.e., shift starts before 08:00)	16.6%	499	2,999	15.3%
Afternoon shifts (i.e. shift starts between 13:00 and 19:59)	10.4%	306	2,947	9.4%
Day shifts (i.e., shift starts between 08:00 and 09:59)	10.2%	282	2,768	8.6%
Mid-day shifts (i.e., shift starts between 10:00 and 12:59)	5.8%	159	2,738	4.9%

2.2.8.7.2 Operational Events at Work

Overall, 18% (581/3224) of respondents indicated that they had a proximity event (PE), Operational Deviation (OD) or Operational Error (OE) in the last year. As can be seen in Figure 2-53, 20.8% (478/2295) of CPCs reported being involved in an operational event in the last year compared to 14.8% (71/481) of Developmentals, and 7.5% (19/253) of the FLMs.

Of those respondents who had been involved in an operational event, 55.9% (320/572) believed that their own fatigue had been a contributing factor. In comparison to those in other positions, CPCs who were involved in an operational event were more likely to believe that fatigue was a contributing factor, as shown in Figure 2-53. Fatigue was cited as a contributing factor by 58.5% (275/470) of the involved CPCs, by 39.4% (28/71) of the involved developmentals, and by 33.3% (6/18) of the FLMs.

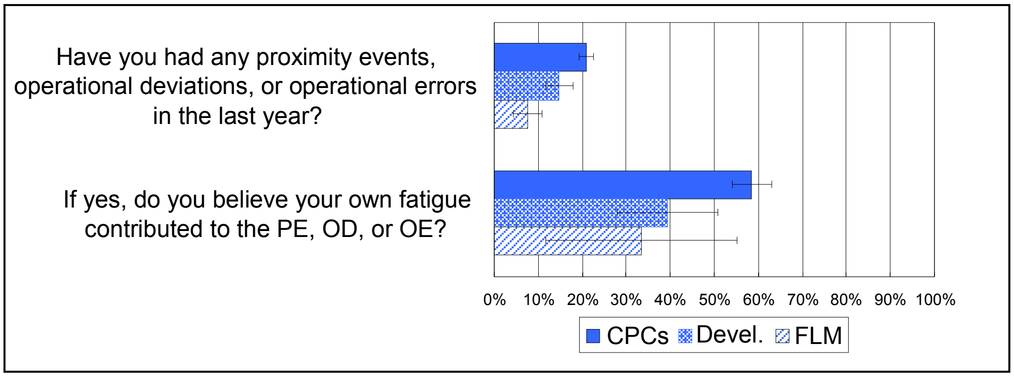

Figure 2-53. Percentage of respondents in three positions who were involved in an operational event and the percentage of these who believed that fatigue had contributed to the operational event. ns = 2295 & 470 CPCs, 481 & 71 Developmentals, and 253 & 18 FLMs. Error bars = 95% CIs.

Figure 2-54 shows that about 33% (153/463) of respondents at TRACONs had experienced an operational event in the previous year, approximately double the proportion at Towers (14.9%, 101/160) and En Route facilities (16.2%, 129/259). Of those personnel at TRACONs and Towers who had experienced an operational event, approximately 60% considered fatigue to have been a factor. Fatigue was less likely to have been considered a factor by personnel at En Route centers.

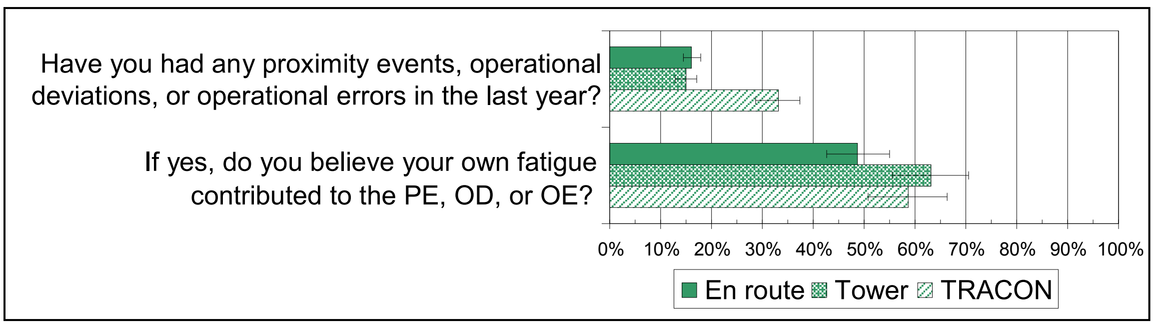

Figure 2-54. Percent of respondents at each facility type who were involved in an operational incident, and the percentage of these who believed that fatigue had contributed to the incident. n = 1633 & 462 En Route, 1091 & 314 Tower, and 463 & 216 TRACON. Error bars = 95% CIs.

Of all respondents who had experienced a fatigue-related incident, approximately 78% identified their work schedule as a cause of their fatigue, as shown in Figure 2-55. Workload was cited by approximately 46%, with family, personal problems, health and commute also identified as causes of the fatigue that contributed to the operational event.

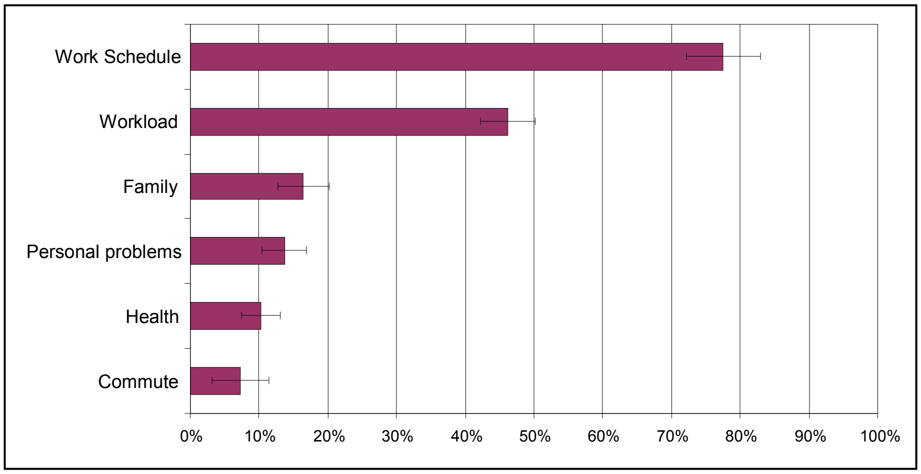

Figure 2-55. Sources of fatigue identified by all respondents who had experienced a fatigue-related operational event (n = 329). Respondents could identify more than one contributing cause, hence the percentages do not add to 100%. (Error bars = 95% CIs.)

2.2.8.7.3 Operational Events and Age

Table 2-58 indicates that CPCs with the highest proportion of reported operational events were between 36 and 40 years. Respondents were asked "Have you had any proximity events (PEs), operational deviations (ODs), or operational errors (OEs) in the last year?"

Table 2-58. Proportion of Reported Operational Events by CPCs by Age

Age	CPCs Have Had Event %	CPCs Have Had Event #	Total Number
25 or under	17.2%	10	58
26–30	22.0%	78	354
31–35	21.1%	60	284
36–40	31.4%	65	207
41–45	20.2%	79	392
46–50	18.7%	126	674
51–55	19.5%	55	282
56+	14.7%	5	34
Averages/Totals	20.9%	478	2,285

Note: Pearson's Chi-Square is 17.8, df 7, p = 0.01.

2.2.9 Extent of Fatigue, Causes and Consequences

2.2.9.1 Level of Fatigue

Respondents frequently (3.8 on a 5 point scale) observe other air traffic controllers who are fatigued at work and believe that fatigue frequently (3.7 on a 5 point scale) impacts other air traffic controllers' ability to perform their job effectively. Respondents indicate that they themselves experience fatigue at work significantly more often (3.4) than "Sometimes," and that fatigue affects their general health and well-being slightly more than sometimes (3.1). However, they indicate that fatigue affects their own ability to perform their job effectively less than "Sometimes" (2.9).

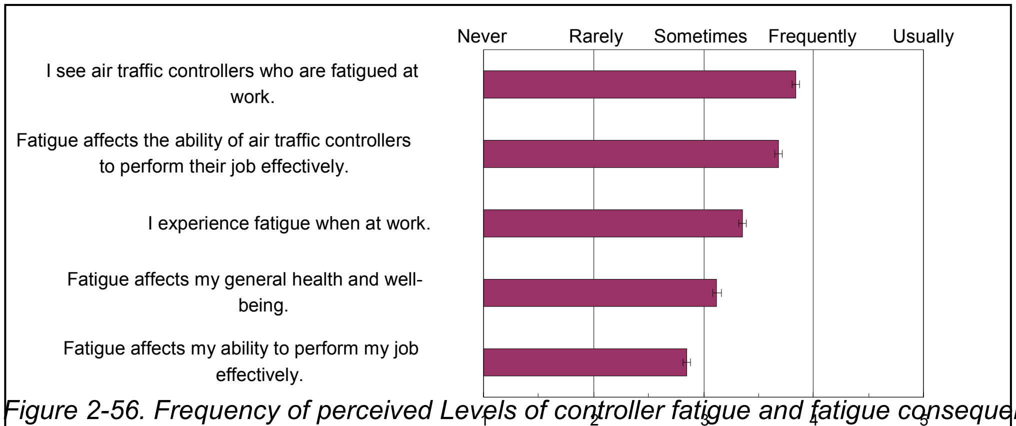

Figure 2-56. Frequency of perceived Levels of controller fatigue and fatigue consequences as seen by all respondents. ns = 3103–3228. Error bars = 95% Confidence Intervals.

Figure 2-57 shows that compared to CPCs and FLMs, Developmentals experience fatigue less frequently at work and feel that it less frequently affects their health and performance.

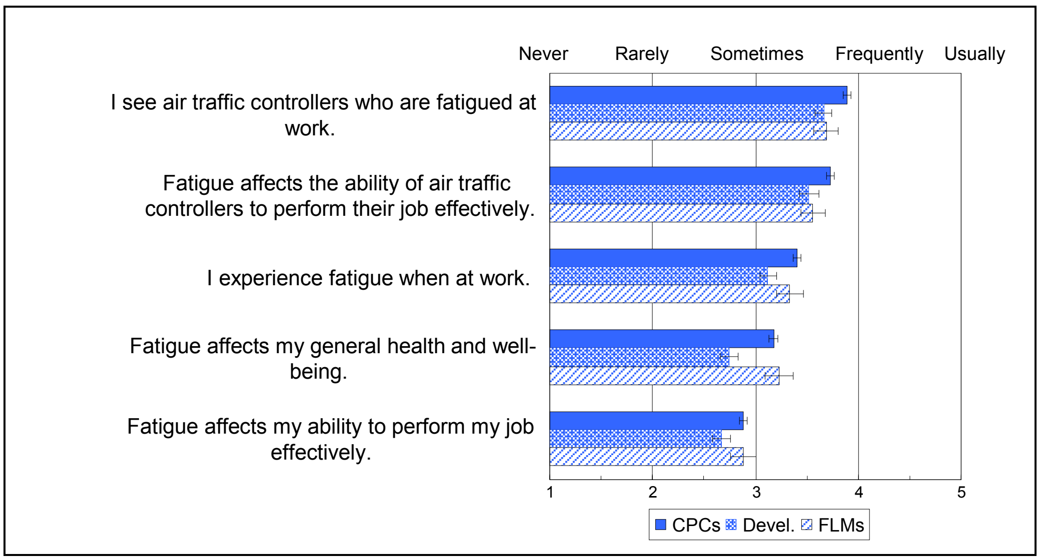

Figure 2-57. Levels of controller fatigue and consequences as seen by CPCs, Developmentals, and FLMs. n = CPCs 2263-2301, Developmentals 463-481, and FLMs 249-252. Error bars = 95% CIs.

TRACON controllers more frequently report seeing and experiencing fatigue than do controllers from other facilities, as shown in Figure 2-58.

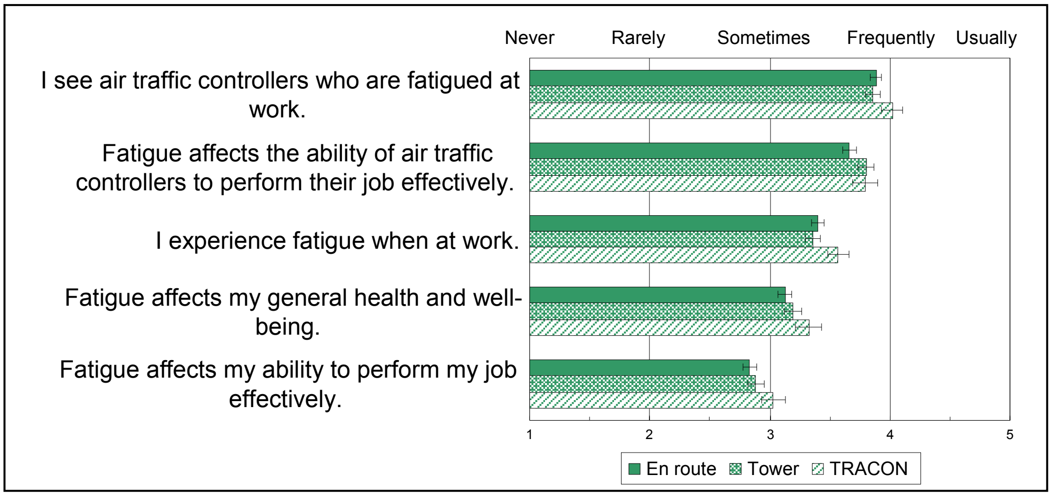

Figure 2-58. Controller fatigue and consequences as seen by CPCs in three facility types. n = En Route 1143-1161, Tower 799-810, and TRACONs 319-326. Error bars = 95% Confidence Intervals.

2.2.9.2 Perception of Fatigue as a Safety Risk

CPCs rate the current level of controller fatigue as a moderate safety risk, as shown in Figure 2-59. There was little difference on perception of risk between those in the three positions, as shown in Figure 2-59.

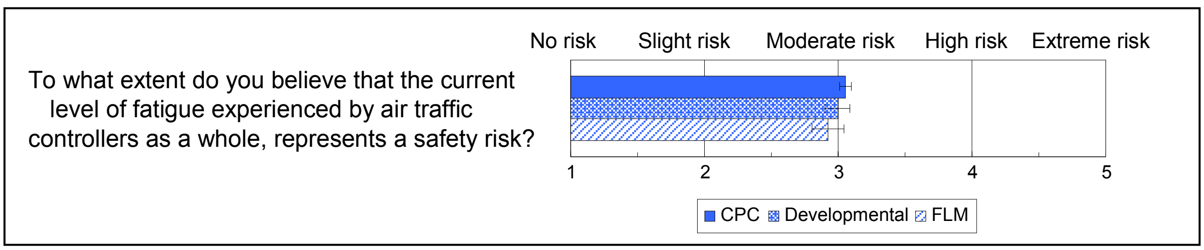

Figure 2-59. Level of risk of current level of controller fatigue as perceived by those in three positions. n = CPCs 2265, Developmentals 459, and FLMs 250. Error bars = 95% Confidence Intervals.

The extent to which controller fatigue was seen as a safety risk was significantly higher in Terminal facilities than En Route facilities, as shown in Figure 2-60.

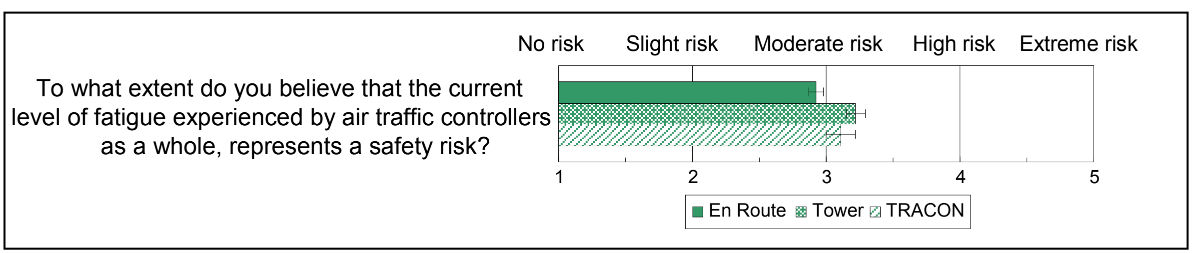

Figure 2-60. Level of risk of current level of controller fatigue as perceived by CPCs according to facility type. n = 1144 for En Route, 797 for Tower, and 322 for TRACONs. Error bars = 95% confidence intervals.

The most frequently selected risk level was the "moderate" level as shown in Table 2-59.

Table 2-59. Number and Proportion of Controllers Assessing the Current Level of

Controller Fatigue at Various Risk Levels		
Perceived Risk	Percent	Frequency
1. No risk	2.2%	51
2. Slight risk	29.6%	686
3. Moderate risk	36.0%	833
4. High risk	20.7%	480
5. Extreme risk	9.3%	215
Subtotal	99.2%	2,265
N/A or Don't know	1.4%	33
Missing	0.8%	18
Total	100.0%	2,316

A significantly higher proportion of those in Terminal facilities rated the risk as high or extreme compared to those in En Route facilities, as shown in Table 2-60.

Table 2-60. Proportion and Number of CPCs who Indicate the Safety Risk of the Current Level of Controller Fatigue to be High or Extreme

Domain	% Indicating High or Extreme Risk	# Indicating High or Extreme Risk	Total CPC Respondents
Tower	37.1%	296	797
TRACON	32.3%	104	322
En Route	25.8%	295	1,144
Subtotal	30.7%	695	2,263
Missing			53
Total			2,316

Note: Pearson's Chi Square = 28.8, df 2, p <0.0001.

2.2.9.3 Causes of Fatigue

CPCs rated their work schedule as most contributing to their fatigue, as shown in Figure 2-61. The controllers were asked, "If you experience fatigue at work, to what extent do you feel the following contribute to your fatigue?" The controllers' work schedule, followed by the related work/life balance, were seen as contributing more to fatigue than the workload/traffic experienced.

Front Line Managers rated work schedule as contributing to their fatigue more than did CPCs, as shown in Figure 2-61.

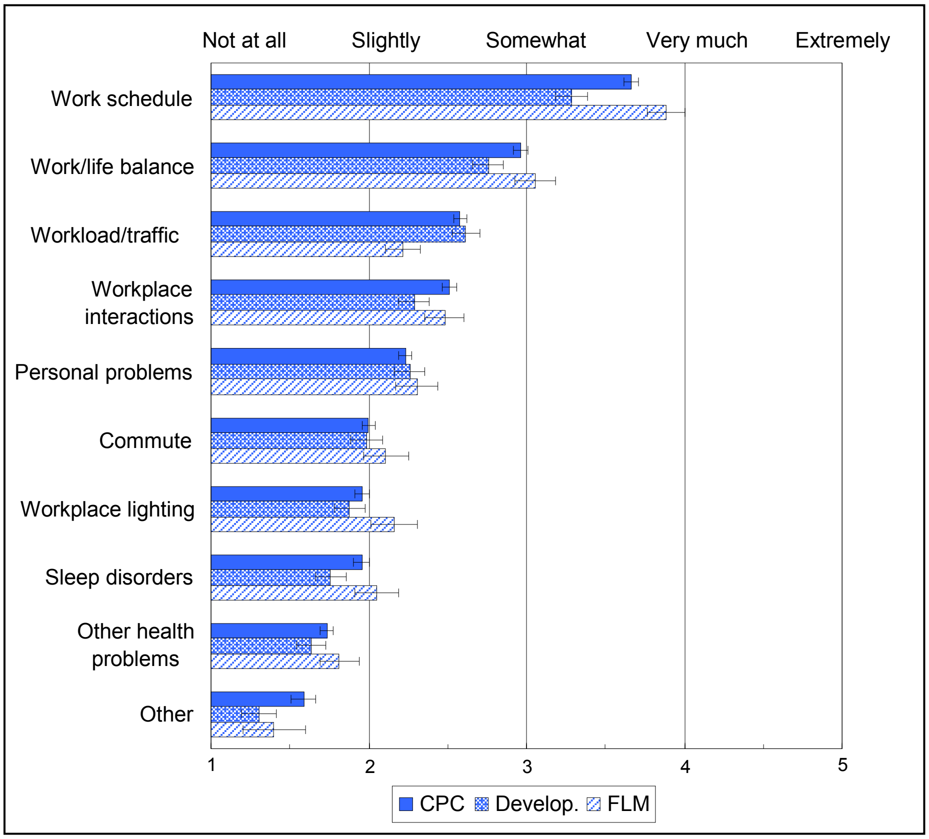

Figure 2-61. Responses by position to "If you experience fatigue at work, to what extent do you feel that the following contribute to your fatigue?". n = CPCs 2245-2274 (Other = 935), Developmentals = 463-468 (Other = 247), and FLMs 242-246 (Other = 98). Error bars = 95% Confidence Intervals.

CPCs from all facility types rated work schedule as the main source of fatigue. As can be seen in Figure 2-62 the contributions to fatigue did not differ very much by facility type, although work schedule was seen as contributing more to fatigue at tower and TRACON facilities than at En Route facilities. Note that workplace lighting contributed significantly less to fatigue in the Tower environment, where there typically is natural lighting during daylight hours.

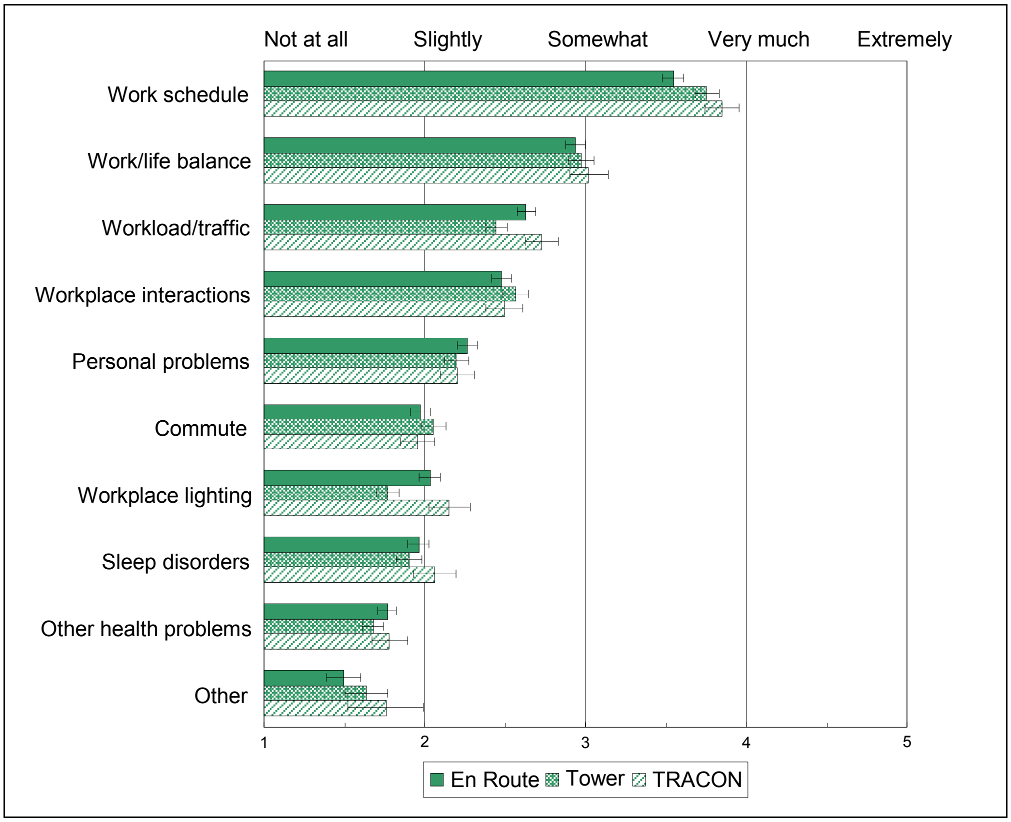

Figure 2-62. CPC responses by facility type to "If you experience fatigue at work, to what extent do you feel that the following contribute to your fatigue?" n for En Route 1128-1146 (Other = 438), Tower 791-801 (Other = 361), and TRACON 323-326 (Other = 136). Error bars = 95% Confidence Intervals.

2.2.10 Suggestions from Respondents on How to Reduce Fatigue

2.2.10.1 Analyzing Respondents' Suggestions

In a free text section of the survey, respondents were asked how controller fatigue could be reduced by:

- Their immediate supervisors or managers,
- Upper level FAA management, and finally,
- Controllers themselves.

All percentages reported in the following sections related to free text inputs are a representation of respondents who provided additional comments. Not all survey respondents provided additional comments.

Good to excellent levels of inter-rater agreement were obtained when coding the free text suggestions provided by respondents. The content of each suggestion was coded; if more than one idea was provided by a respondent, each idea was individually coded. The reliability of the coding was checked by two analysts independently coding a sample of responses from each of the three questions, and the level of inter-rater agreement was calculated using Cohen's Kappa statistic. For the three questions, Kappa was as follows: supervisor actions to reduce fatigue, Kappa = 0.72; management actions to reduce fatigue, Kappa = 0.83; controller actions to reduce fatigue, Kappa = 0.84. Using the guidelines of Fleiss (1981), these are "good" to "excellent" levels of inter-rater agreement.

2.2.10.2 Suggestions for Immediate Supervisors from All Respondents

Respondents were asked, "What, if anything, could your immediate supervisors or managers do to reduce controller fatigue?" Over half of the respondents (53%, 1729/3268) provided suggestions to this question.

The most frequent suggestion, offered by 20.7% of these respondents, was to staff positions only when necessary, as shown in Figure 2-63. The second most frequent suggestion, offered by 20.2% of respondents, was to allow naps during breaks. The third most frequent suggestion, offered by 12.8% of respondents, was to have more or longer breaks. In some cases, respondents stated that breaks were too brief to enable them to mentally refresh after time on position, or were not long enough for meals. The next most frequent suggestion was made by 11.5% of respondents who recommended that quick turnarounds be eliminated or reduced. Furthermore, 11.3% of respondents suggested that rapidly rotating shifts should be replaced with straight shifts.

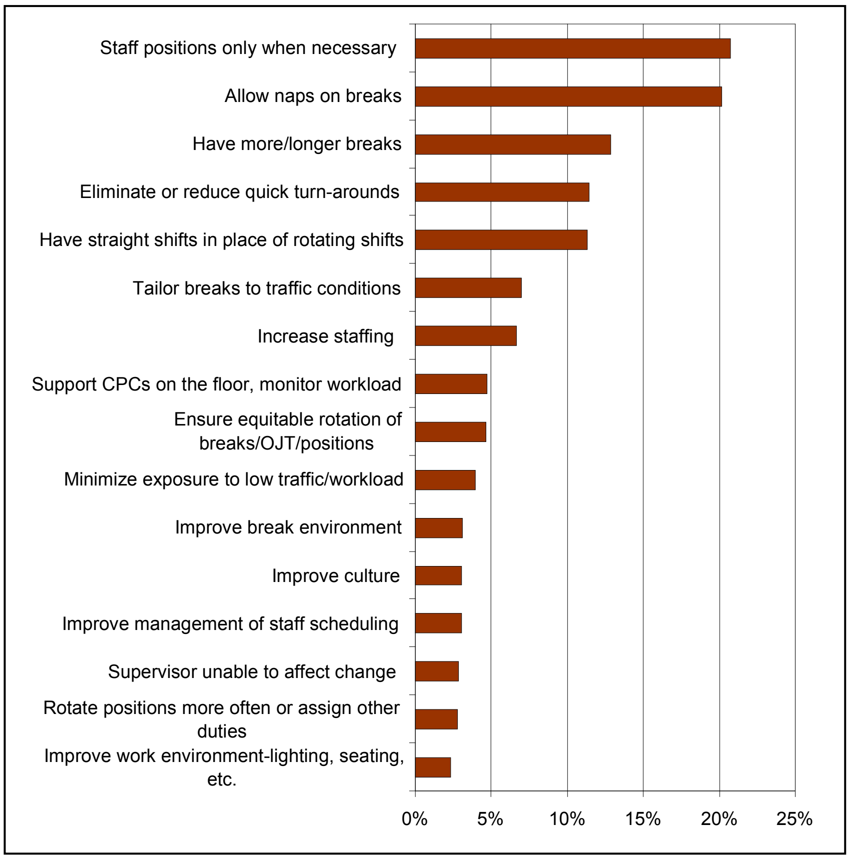

Figure 2-63. Responses to the question,” What, if anything, could your immediate supervisors or managers do to reduce controller fatigue?” as a percentage of those who offered a response to this question. n = 1729. Respondents could make multiple comments, hence percentages do not add to 100%.

2.2.10.3 Suggestions for Immediate Supervisors by Position

As shown in Figure 2-64, 23.7% of the CPC respondents made the suggestion that positions be staffed only when warranted by traffic, but only 6.4% of FLM respondents made that suggestion.

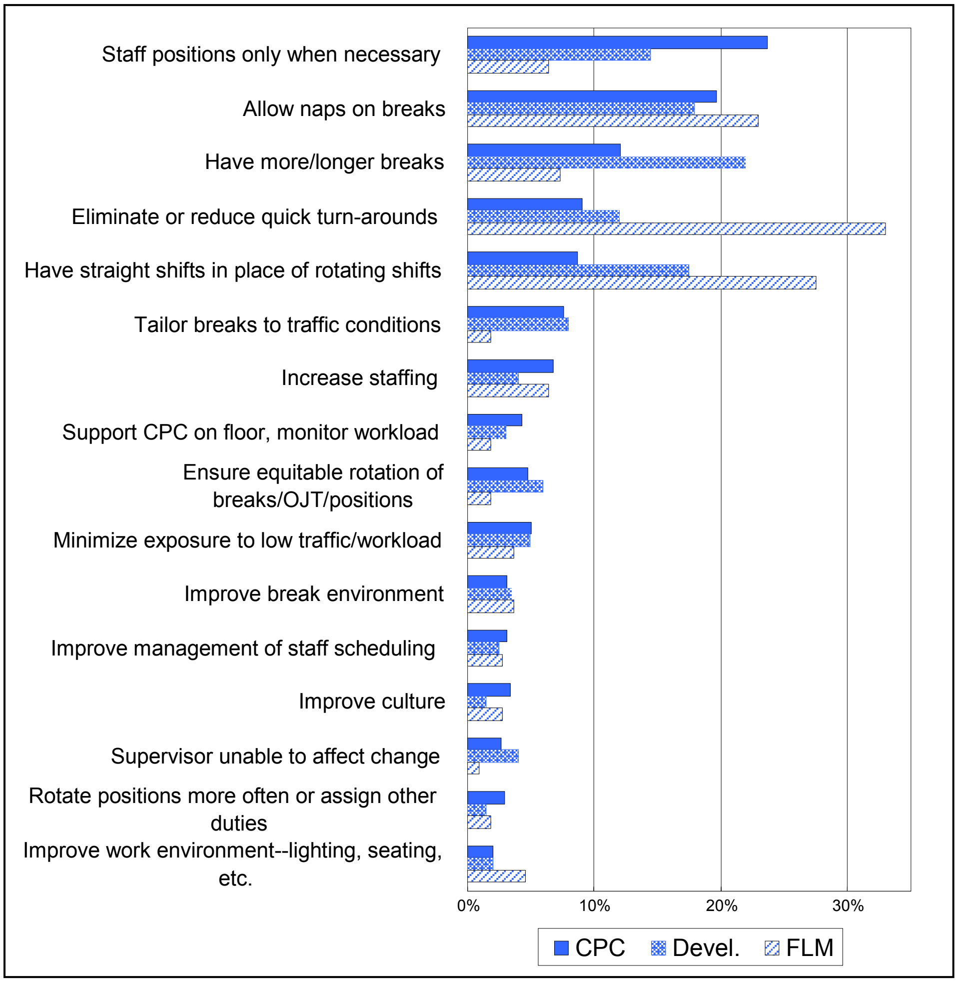

Figure 2-64. Responses to the question "What, if anything, could your immediate supervisors or managers do to reduce controller fatigue?" by respondents' position, as a percentage of those who offered comments to this question. n = 1365 CPCs, 202 Developmentals, 109 FLMs. Respondents could make multiple comments, hence percentages do not add to 100%.

Front Line Managers (33.0%) were more likely to suggest the elimination or reduction of the quick turn-arounds. Developmentals (29%) were more likely to suggest more or longer breaks.

2.2.10.4 Suggestions for Immediate Supervisors by Facility Type

As shown in Figure 2-65, about a third (30.1%) of respondents from En Route facilities suggested that positions should be staffed only when traffic requires it, compared to 8.4% from Tower and 17.1% from TRACON facilities. The suggestion that naps be allowed during breaks was made more often by Tower respondents (25.5%) than by respondents at other facilities. Staff from Tower facilities (16.1%), were also more likely to suggest a reduction in 'quick turns' and the introduction of straight shifts than respondents from other facility types.

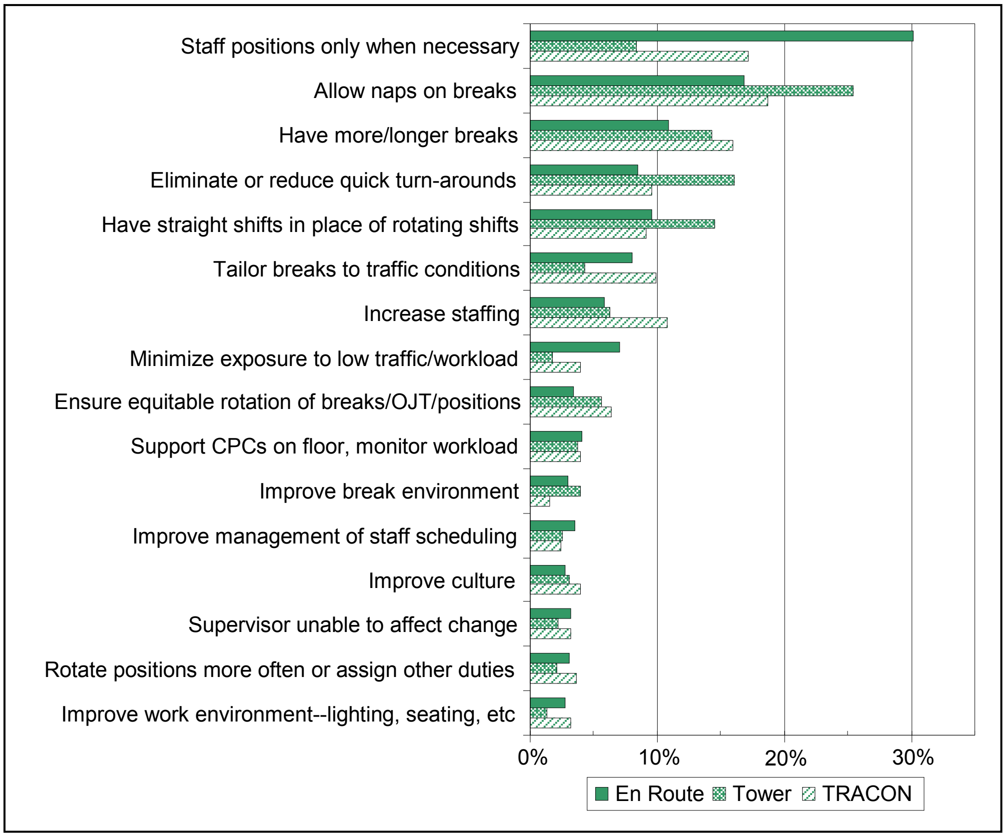

Figure 2-65. Responses to the question "What, if anything, could your immediate supervisors or managers do to reduce controller fatigue?" by facility, as a percentage of those who offered comments to this question.ns = 880 En Route, 585 Tower, and 251 TRACON. Respondents could make multiple comments, hence percentages do not add to 100%.

2.2.10.5 Suggestions for Upper-Level FAA Management by All Respondents

Respondents were asked, "What, if anything, could your immediate supervisors or managers do to reduce controller fatigue?" Over half of the respondents (56%,1820/3268) provided suggestions to this question.

The most frequent suggestion was that management should allow controllers to take naps during breaks at work (28%), as shown in Figure 2-66. About 17% of those responding suggested increased staffing. Approximately 11% of those responding suggested the reduction or elimination of quick turn-arounds. Approximately 9% of those responding suggested introducing straight shifts, or slowly rotating shifts in place of rapidly rotating shifts.

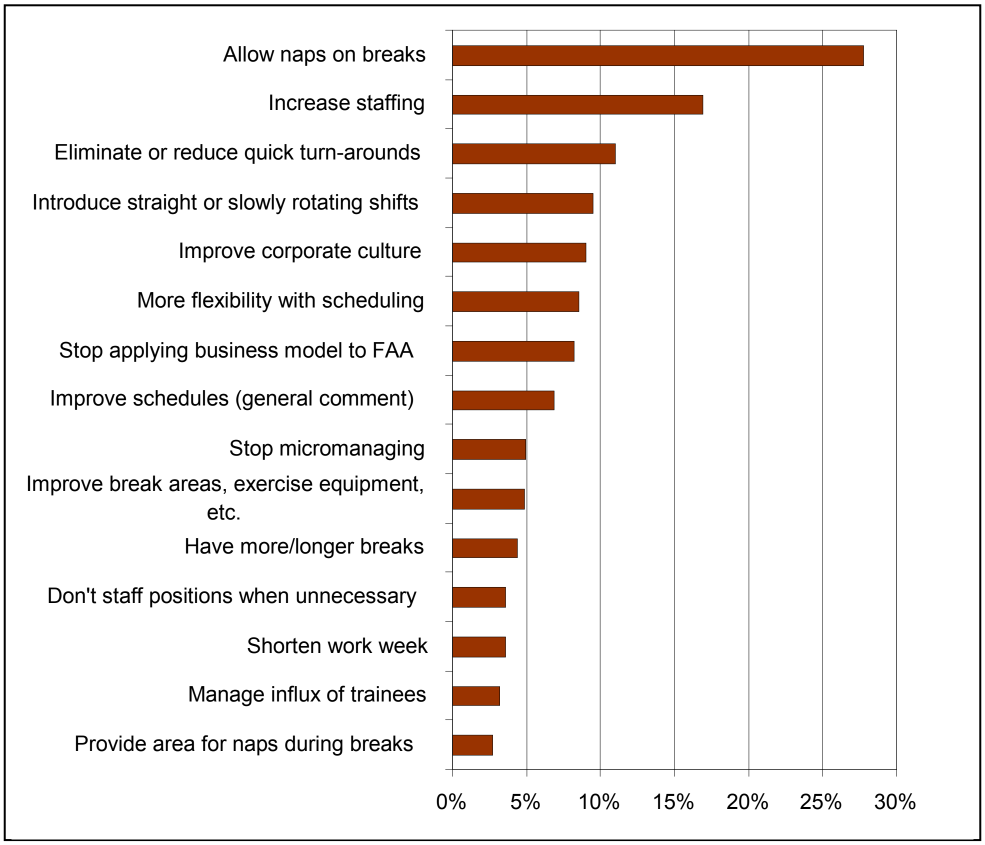

Figure 2-66. Suggestions in response to the question, "What, if anything, could upper-level FAA management do to reduce controller fatigue?" as a percentage of the 1837 who responded to the question. Respondents could make multiple comments, hence percentages do not add to 100%.

2.2.10.6 Suggestions for Upper-Level FAA Management by Position

As shown in Figure 2-67, about 25% of Front Line Managers suggested that schedules should be revised to eliminate or reduce the need for quick turn-arounds. Another 24% of FLM respondents suggested that schedules should be changed to straight or slowly rotating types. Approximately 11% of CPCs suggested that the FAA aim to improve their corporate culture. Another 10% of CPCs suggested that scheduling could be made more flexible to allow for individual needs.

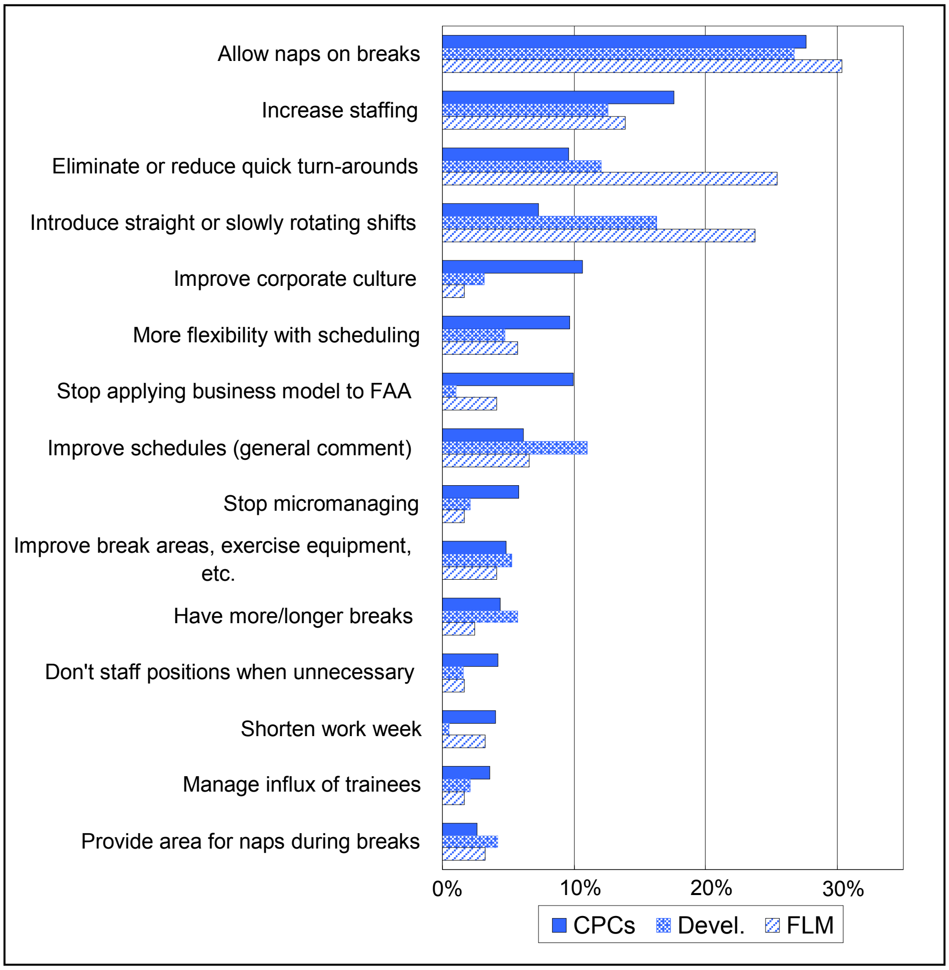

Figure 2-67. Responses to the question, "What, if anything, could upper-level FAA management do to reduce controller fatigue?" as a percentage of the 1837 who responded to the question, by job title. n = 1414 CPCs, 191 Developmentals, 122 FLMs. Respondents could make multiple comments, hence percentages do not add to 100%.

2.2.10.7 Suggestions for Upper-Level FAA Management by Facility Types

Figure 2-68 summarizes the comments broken down by facility type. It can be seen that 25% of respondents from TRACON facilities suggested that staffing be increased so as to result in improvements in schedules. A suggestion offered by 14% of staff from Towers was to change schedules to reduce or eliminate quick turns. About 12% of respondents at En Route facilities, more than at other facilities, suggested that the FAA not apply a business model to air traffic control.

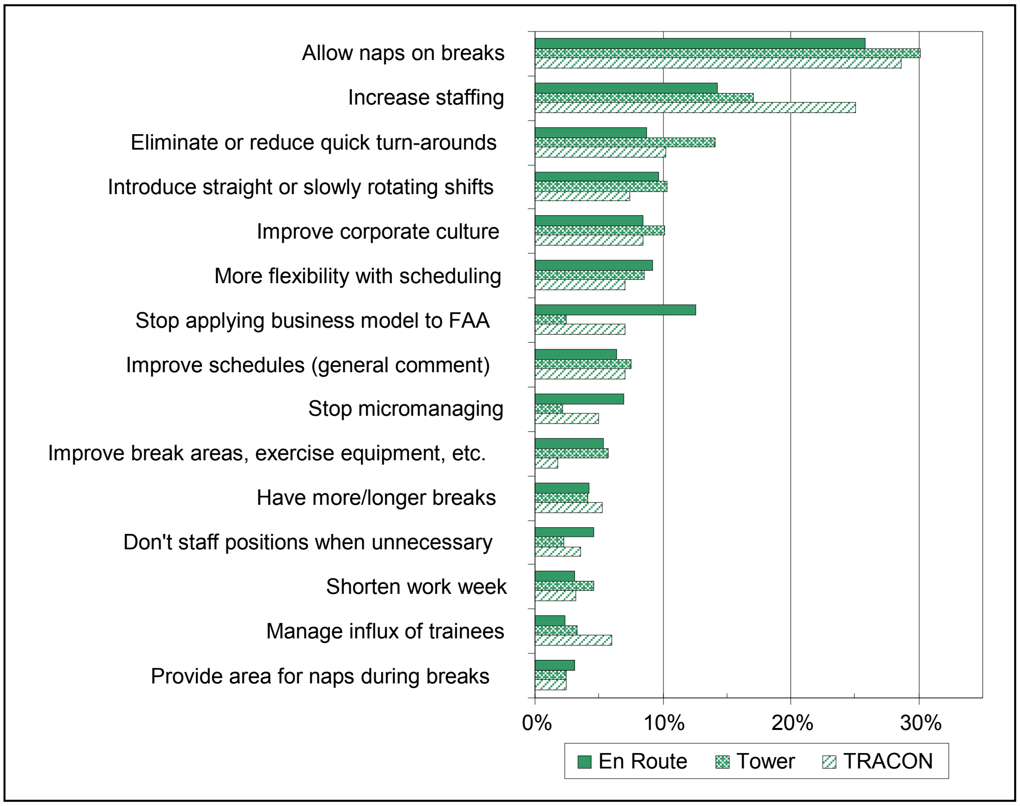

Figure 2-68. Suggestions in response to the question, “What, if anything, could upper-level FAA management do to reduce controller fatigue?” as a percentage of the 1837 who responded to the question, by facility. n = 810 En Route, 610 Tower, and 283 TRACON. Respondents could make multiple comments, hence percentages do not add to 100%.

2.2.10.8 Suggestions for Controllers by All Respondents

Respondents were asked, "What, if anything, could controllers do to reduce their fatigue?" About 46% (1501/3268) of all respondents provided suggestions to this question.

The most frequent (48%) suggestion was that controllers should use sleep strategies and discipline, as shown in Figure 2-69. The second most frequent suggestion (38%) involved the need to optimize health. Approximately 19% suggested that controllers could take a role in improving their schedules. About 17% suggested that controllers take naps. About 8% of the suggestions related to fatigue awareness and fatigue management strategies.

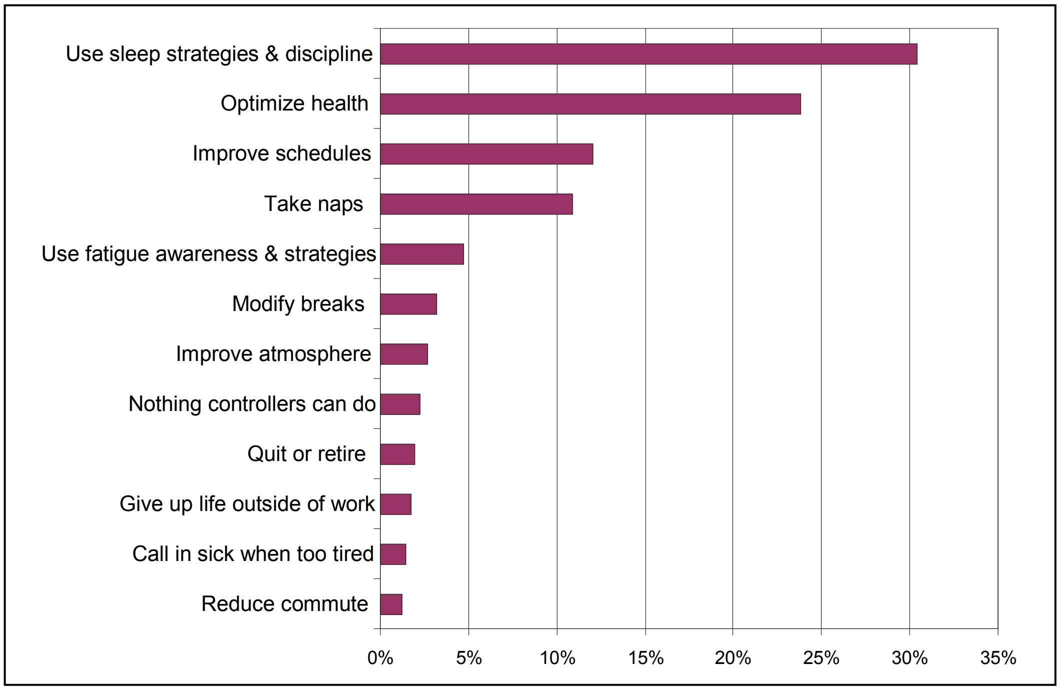

Figure 2-69. Suggestions in response to the question "What, if anything, could controllers do to reduce their fatigue?" as a percentage of the 1501 who responded to the question. Respondents could make multiple comments, hence percentages do not add to 100%.

2.2.10.9 Suggestions for Controllers by Position

As shown in Figure 2-70, CPCs (12%) were more likely to recommend naps than FLMs (4%). CPCs (29%) were less likely than developmentals (38%) and FLMs (37%) to recommend using sleep strategies and discipline. FLMs were more likely to state that controllers needed to develop good sleep habits and create home conditions conducive to sleep. Some FLMs (16%) suggested that schedules should be revised, including eliminate or reduce the need for quick turns. This suggestion was also made by CPCs (12%) but less by developmentals (6%).

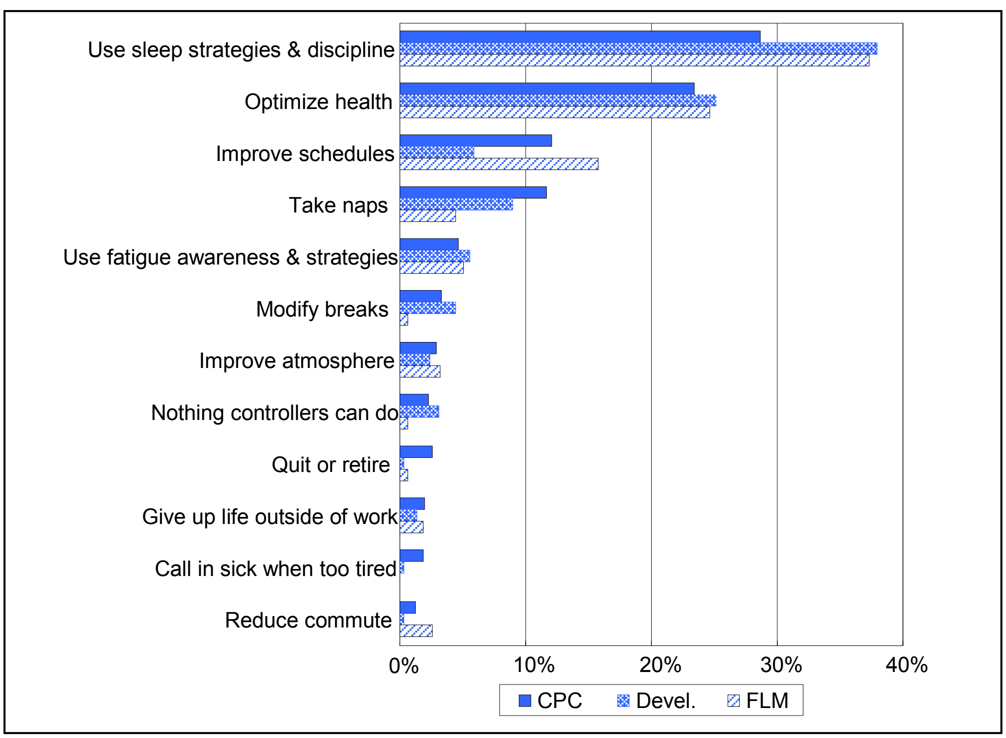

Figure 2-70. Responses to the question "What, if anything, could controllers do to reduce their fatigue?" as percentage of the 1501 who responded to the question, by position. n = 1775 CPCs, 290 Developmentals, 185 FLMs. Respondents could make multiple comments, hence percentages do not add to 100%.

2.2.10.10 Suggestions for Controllers by Facility Type

Figure 2-71 indicates that the responses on what controllers could do to reduce fatigue were very similar across facility types. The top two controller responses on how they can reduce their fatigue were "use sleep strategies & discipline" and "optimize health".

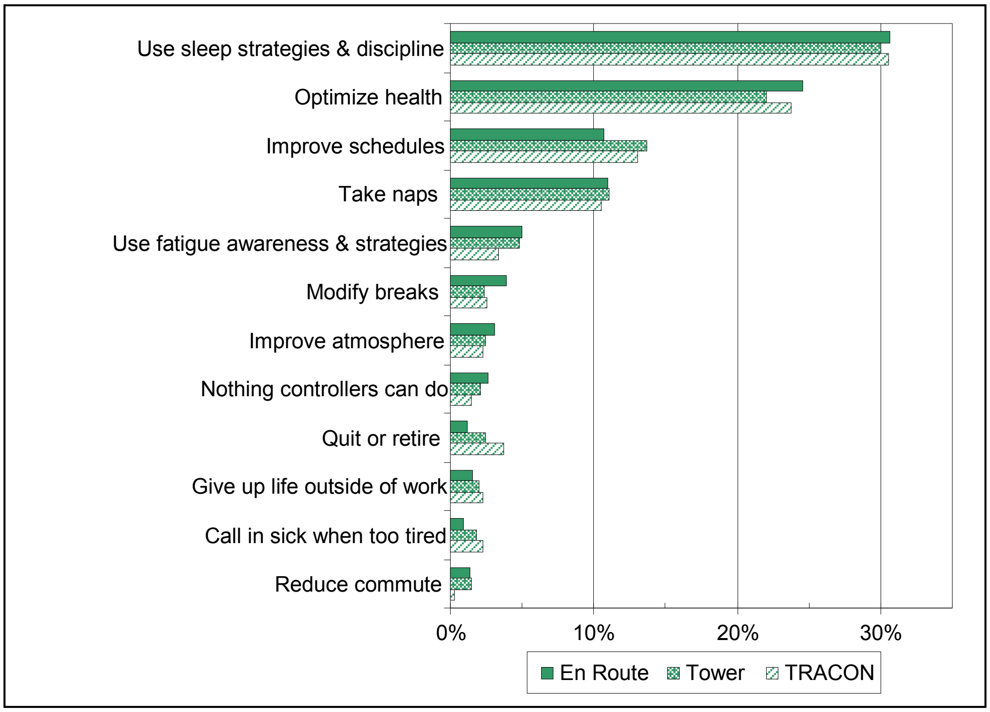

Figure 2-71. Responses to the question "What, if anything, could controllers do to reduce their fatigue?" as percentage of the 1501 who responded to the question, by facility. n = 1172 En Route, 812 Tower, and 353 TRACON. Respondents could make multiple comments, hence percentages do not add to 100%.

2.2.10.11 Training

Over half of the CPCs answered "Yes" to the question "Would you like training or information on ways to reduce fatigue?" This did not vary significantly by facility type. It varied slightly by position, with Developmentals being somewhat less interested in training on ways to reduce fatigue, as shown in Table 2-61.

Table 2-61. Proportion of Respondents Who Would like Training or Information on Ways to Reduce Fatigue

Respondent	Yes %	Yes #	Total
CPC	53.60%	1,152	2,150
FLM	49.80%	110	221
Developmental	46.10%	201	436
Total	52.21%	1,463	2,807

Note: Pearson's Chi Square = 8.7, df 2, p = 0.01.

Those who had midnight shifts in their schedules were more likely to want training or information, as shown in Table 2-62.

Table 2-62. Proportion of Those With and Without Midnight Schedules Who Would like Training or Information on Ways to Reduce Fatigue			
	Would Like Training		
Schedule	%	#	Total
No midnights	49.8%	805	1,617
Have midnights	55.1%	755	1,369
Average/Total	52.2%	1,560	2,986

Note: Pearson's Chi Square = 8.6, df 1, p <0.01.

2.2.10.12 Staying Home from Work When Fatigued

About two thirds of the CPCs indicated that they had called in sick due to fatigue at least once, and about half used some annual leave for fatigue, as shown in Table 2-63.

Table 2-63. Proportion and Number of CPCs that Called in Sick or Took Annual Leave Due to Fatigue

	How often, in the last year, have you called in sick because you were fatigued?		How often, in the last year, have you taken annual leave due to fatigue?	
Number of times	%	#	%	#
0 times	33.20%	768	47.60%	1,102
1-2 times	35.80%	828	25.80%	597
3-5 times	23.00%	532	16.70%	387
6-10 times	5.50%	128	5.30%	122
10+ times	1.60%	36	2.70%	62
Missing	1.00%	24	2.00%	46
Total	100.00%	2,316	100.00%	2,316

CPCs identified their comfort level for taking time off from work due to fatigue between not very and somewhat comfortable, as shown in Figure 2-72. CPCs were even less comfortable telling their supervisor that they want to take time off due to fatigue.

The reluctance to take time off from work due to fatigue or tell their supervisor that they are doing so is manifested by those in all job categories, as shown in Figure 2-72. However, there are some differences between the three groups. FLMs feel less comfortable than CPCs and developmentals in taking time off because of fatigue. FLMs see their own supervisors as more willing to authorize annual leave to reduce fatigue than do CPCs.

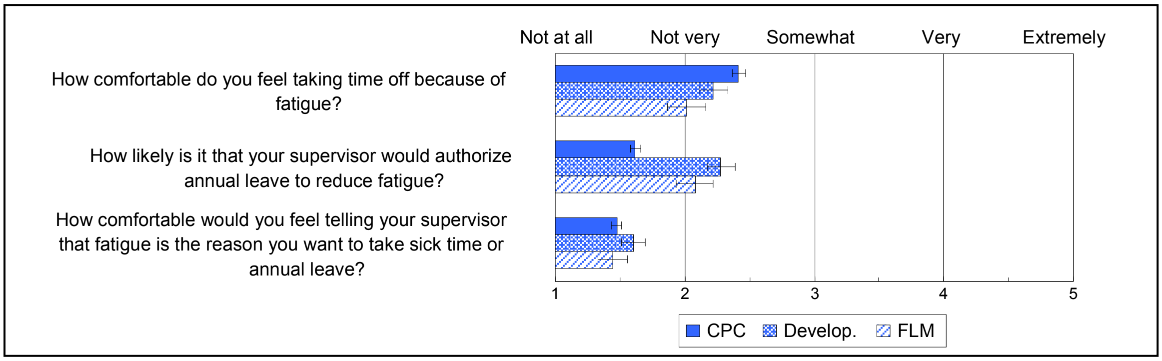

Figure 2-72. Ratings by position of comfort levels in taking time off from work due to fatigue, informing supervisors of the reason, and the likelihood of supervisors' authorization to do so. n = 2222-70 CPC, 427-465 Developmentals, and 239-40 FLM. Error bars = 95% Confidence Intervals.

Controllers from Towers are slightly more likely to think that their supervisors would authorize annual leave to reduce fatigue, as shown in Figure 2-73, but the mean response is between "Not at all" and "Not very".

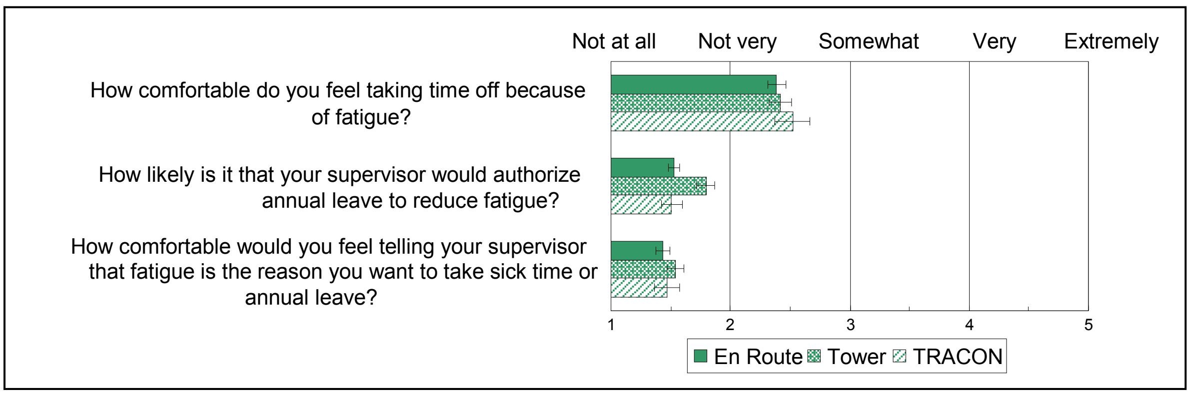

Figure 2-73. CPC ratings by facility of comfort levels in taking time off from work due to fatigue, informing supervisors of the reason, and the likelihood of supervisor's authorization to do so. n = 1121-44 for En Route, 777-799 for Tower, and 323-6 for TRACON. Error bars = 95% Confidence Intervals.

2.2.11 Job Satisfaction

CPCs more than slightly agree with the statement that they are satisfied with their job (5.6 on a 7-point scale) and disagree with the statement that they frequently think of quitting (2.7 on a 7-point scale), as shown in Figure 2-74. Developmentals are slightly more satisfied with their job than CPCs and do not think of quitting as frequently.

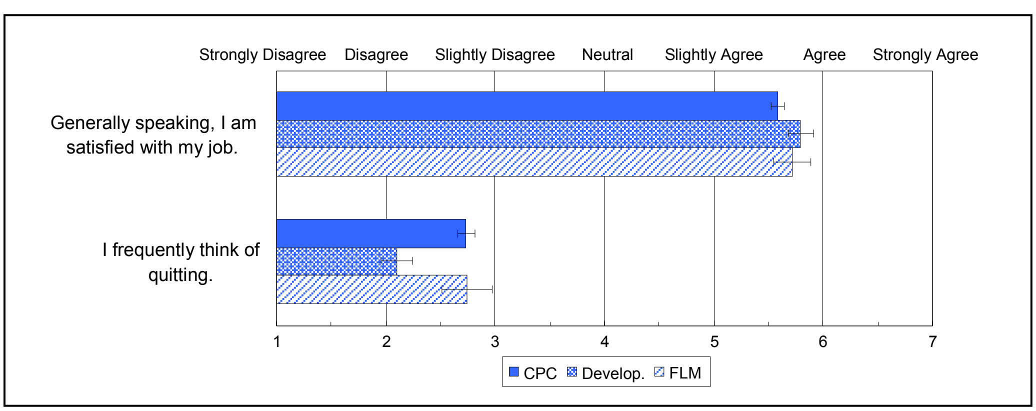

Figure 2-74. Position by job satisfaction on a 7-point scale. n = 2293-5 CPC, 475-6 Developmental, 249 FLM. Error bars = 95% Confidence Intervals.

CPCs in En Route facilities reported level of satisfaction with their job is significantly higher than ratings from other facilities as shown in Figure 2-75. CPCs in En Route facilities also reported being less likely to think about quitting their jobs than CPCs in other facilities.

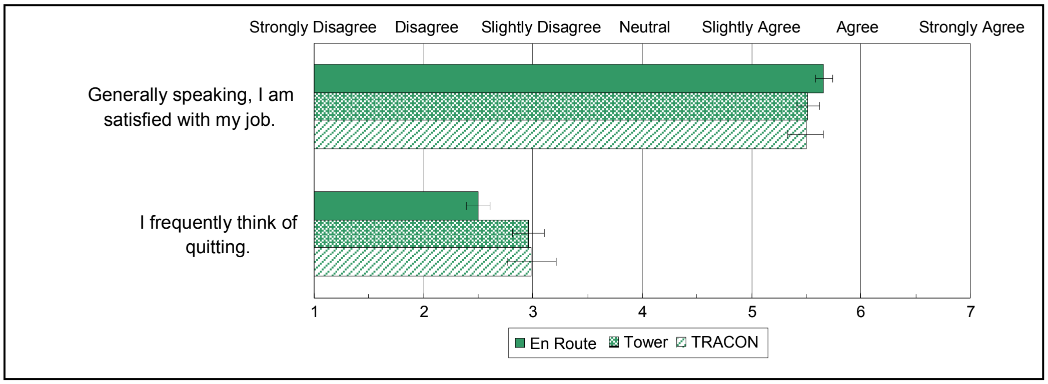

Figure 2-75. CPCs' mean ratings of job satisfaction by facility type on a 7-point scale. n = 1157-9 En Route, 810-12 Tower, and 323-5 TRACON. Error bars = 95% Confidence Intervals.

2.2.11.1 Satisfaction with Various Aspects of Job

Schedule was the aspect of their job that controllers were most dissatisfied with, as shown in Figure 2-76. They also identified schedule as most contributing to their fatigue (see Figure 2-43). Controllers were asked to indicate their level of satisfaction or dissatisfaction with various aspects of their job. CPCs were most satisfied with the type of work that they were doing and their relations with their co-workers. In addition to schedule, the controllers were least satisfied with their job's influence on their health and well-being.

Differences emerged between the CPCs, FLMs, and Developmentals regarding their satisfaction with various aspects of their jobs. As shown in Figure 2-76, FLMs were less satisfied than the others with both the type of work they do and their schedule, but more satisfied with their relations with supervisors. Developmentals were more positive (neutral) than the others regarding their schedule and their job's influence on their health and well-being and life-work balance issues. Developmentals were also more positive than the CPCs regarding their relations with supervisors.

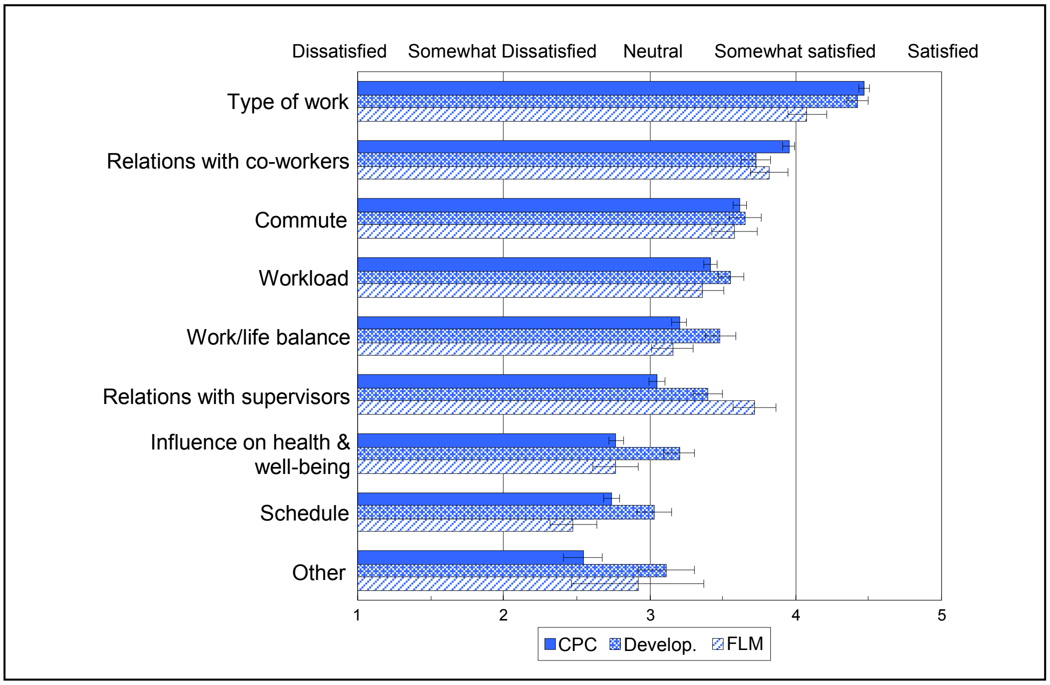

Figure 2-76. Satisfaction or dissatisfaction with various aspects of work by position. n = 2293-9 CPCs, 478-80 Developmentals, and 247-8 FLMs. n for "Other" were 370 for CPCs, 106 for Developmentals, and 25 for FLMs. Error bars = 95% Confidence Intervals.

Of all controllers, TRACON CPCs were most dissatisfied with their schedules, followed by those who work in Towers, as shown in Figure 2-77. Those who work in En Route facilities were neutral with regard to their schedules. Similarly TRACON CPCs were more dissatisfied with their job's influence on their health and well-being. Those who work in TRACONs were significantly more satisfied with their relations with supervisors than were those from other facility types. CPCs from all facilities were most satisfied with the type of work they do. Those from Towers were less satisfied than others with their relations with co-workers.

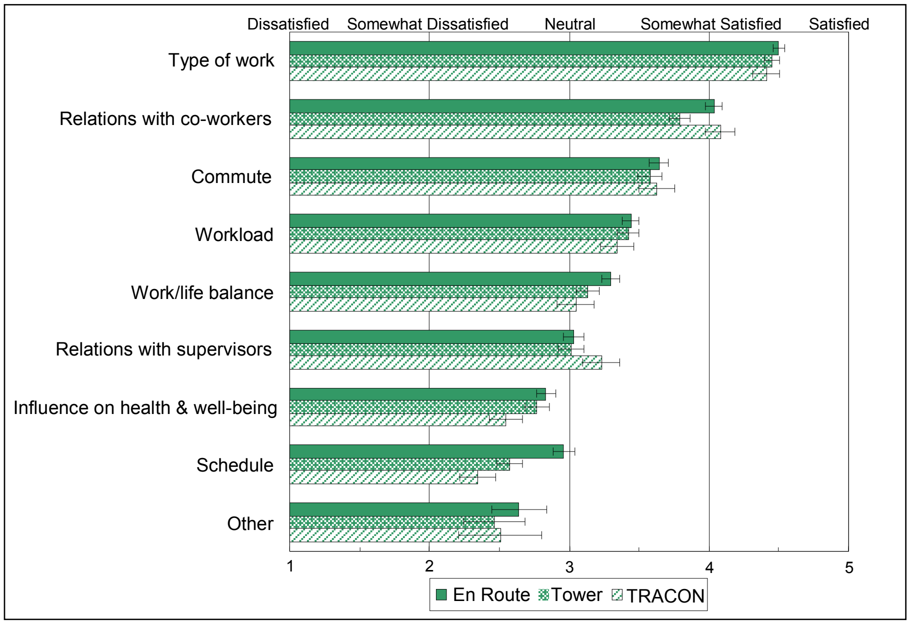

Figure 2-77. Facility type by satisfaction or dissatisfaction with various aspects of CPCs' jobs.n = 1159-1161 En Route, 807-812 Tower, and 325-7 TRACON. "Other" n are 153 En Route,152 Towers, and 65 TRACON. Error bars = 95% Confidence Intervals.

2.3 SURVEY SUMMARY AND DISCUSSION

2.3.1 Work Context for Fatigue Findings

ATC personnel in general indicated that they were satisfied with their job and the type of work it entailed. In general, they reported good relations with their co-workers and did not report a high level of stress at work. Personnel in all three positions (CPC, developmental, and FLM) indicated that they could usually keep up with their workload, as did CPCs from all facility types (Towers, TRACONs, and En Route Centers). Supervisors were perceived as supporting controllers in their work by assigning additional staff or by splitting a position when requested, if staffing permitted. In general, the number of hours worked and the overall workload were reported to be “about right”.

2.3.2 Controller Fatigue Levels

Controllers reported they experienced fatigue and also perceived fatigue in their colleagues. The current ATC personnel sample was significantly more fatigued, based on their responses to the Chronic Fatigue Scale, than a normative comparison group of nurses and industrial shift workers (Barton et al., 1995). The same scale and comparison group was used in the previous 1999 ATC survey (Della Rocco et al., 2000a). Respondents in the current study were also significantly more fatigued than the comparable sample of CPCs and Developmentals in the1999 survey population.

In comparison to the 1999 study, there is evidence that the 2010 sample had a lower proportion of straight shifts without midnights and a higher proportion of counter-clockwise rapidly rotating schedules, especially with midnights.[8]

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8 Beyond these general statements, it is difficult to compare the 1999 and the 2010 schedules since only 67% of the schedules from the 1999 survey were categorized into four types (Della Rocco et al., 2000a). In the 2010 survey data, 88.5% of the schedules could be categorized into these four types and all but 2.7% of the schedules could be classified into the five schedule types that were the focus of the 2010 data analysis.

2.3.3 Fatigue Due to Schedule

Of all aspects of their jobs, ATC personnel reported being least satisfied with their schedules and felt that their schedules contributed most to their fatigue. When asked to indicate why they might have trouble sleeping, the highest proportion of respondents (68%) identified "Shift work" as the reason. Of all respondents who had experienced a fatigue-related operational event, approximately 78% identified their work schedule as a cause of their fatigue. The likelihood of their being "about to doze off during work duties" was highest during certain shift types: midnights after a quick turn-around, successive midnights, and early morning shifts after a quick turn-around. These shift types were more strongly related to reported fatigue than were shifts with either high or low workloads.

2.3.4 Reported Sleep Compared with Earlier Studies

In contrast to the 1999 survey, the 2010 survey differentiated between sleep obtained on "an early shift" with sleep obtained on "an early shift after a very quick turn-around." ("A very quick turn-around" referred to a shift rotation with 8 or 9 hours between shifts.) The amount of sleep obtained on an early shift in the 1999 survey (6.5 hours), was similar to that obtained in the 2010 survey (6.3 hours). However, both were far more than the 5.4 hours reported before an early shift *after a very quick turn-arou*nd in the 2010 survey—which was identical to that found in the objective field study associated with the 1999 study (Della Rocco & Nesthus, 2005) and similar to the 5.2 hours found in the 2010 field study (see section 3.3.3.5 of this report). It is likely that the 1999 survey overestimated the number of hours slept before early shifts after a very quick turn-around.

Also in contrast to the 1999 survey, instead of only obtaining data on the amount of sleep obtained before "a midnight shift," the 2010 survey differentiated between sleep obtained on "successive midnight shifts," and "sleep obtained before a midnight shift after a very quick turn-around." In the current 2010 survey results, the average reported sleep was 5.5 hours between *successive* midnight shifts —further reduced to 3.1 hours after a very quick turn-around. This compares to 3.6 hours before "a midnight shift" in the 1999 survey (Della Rocco, et al., 2000a, p. 25). The field study associated with the 1999 survey found a total of 2.3 hours of sleep before a midnight shift following a very quick turn-around (Nesthus, et al., 2001), a level almost identical to that found in the present field study (2.5 hours, described in section 3.3.3.5).

As can be seen in Table 2-64, the amount of sleep obtained by ATC personnel in the 2010 survey was generally lower than that found in the 1999 survey before comparable shifts. In addition, the amount of objectively measured sleep obtained by controllers in the 2010 field study is consistently less than reported in the 2010 survey.

Respondents indicated they need on average 7 to 8 hours of sleep per night.

Table 2-64. Hours Slept before Various Shifts from Four Different Data Sets							
Shift Type		*2010 Survey* Mean Hours	n	*1999 Survey*[a] (n = 4524) Mean Hours	*2010 Field Study* Mean Hours	n	*2000 Field Study* (n =71) Mean Hours
On RDOs not following a midnight shift		8.3	3,065	8.3	-	-	8.0[c]
Before an afternoon shift (starts between 13:00 &19:59)		7.7	2,987	8.0	6.9	327	7.2[b]
Before a mid-day shift (starts between 10:00 & 12:59)		7.3	2,431	7.9	6.8	111	7.7[b]
Before a day shift (starts between 08:00 & 09:59)		6.7	2,434	7.3	6.4	14	6.5[b]
Before an early shift (starts before 08:00)		6.3	3,126	6.5	5.4	369	5.8[b]
Before an early shift following…	8-9 hours off	5.4	2,819				
	8-10 hours off				5.2	148	5.4[c]
	8-12 hours off				5.3	164	
Before a midnight shift following…	8-9 hours off	3.1	1,959				
	8-10 hours off						2.3[b]
	8-12 hours off				2.5	52	
Before a midnight shift		-	-	3.6	3.3[d]	140	-
Before a midnight shift after another midnight shift		5.5	1,228	-	-	-	-
After a midnight shift during the day		4.8	1,738	4.3	-	-	4.5[b]

Note [a] Reported in Della Rocco, et al., 2000a.
[b] Reported in Nesthus, et al., 2001.
[c] Reported in Nesthus, et al., 2003.
[d] The mean hours slept prior to midnight shifts in the field study represents all midnight shifts regardless of time off before the shift.

2.3.5 Chronic Fatigue Scale Comparison

The mean score for the survey respondents on the Chronic Fatigue Scale was significantly higher than the score used for normative comparison in the 1999 survey. The mean score obtained with the current respondents was 26.61 (n = 3126, SD = 8.31), while the normative mean score cited for this scale was 25.04 (n = 1864 nurses and industrial shift workers, SD 7.58, Barton et al., 1995, see also Della Rocco, 2000, p. 15). The difference was significant (t = 6.67, df 4,988, two-tailed p <0.0001).

The mean score for the subgroup of CPCs and developmentals was significantly higher in the current survey respondents than it was for the comparable subgroup in the 1999 survey population. This suggests that chronic fatigue has increased in the operational ATC population. The mean score for the 1999 ATC sample (5,211 CPCs and developmentals) on the Chronic Fatigue Scale was 24.75, SD = 8.32 (Della Rocco, 2000, p. 15). For the comparable respondents in the 2010 sample

(2,692 CPCs and developmentals) the mean was 26.43, SD = 8.24. This is statistically significant (t = 8.53, df 7901, two-tailed p <0.0001).

2.3.6 The 2-2-1 Schedule: Pros and Cons

As discussed in the introduction, the focus of much previous research is the common rapidly rotating counterclockwise "2-2-1" schedule. A summary of this research is provided in Della Rocco & Nesthus, 2005. A typical schedule of this type consists of:

- **2** Afternoon shifts, e.g.
  - 15:00 to 23:00 (followed by 15 hrs. off)
  - 14:00 to 22:00 (followed by 9 hrs. off)
- **2** Day shifts, e.g.
  - 07:00 to 15:00 (followed by 14 hrs. off)
  - 06:00 to 14:00 (followed by 8 hrs. off)
- **1** Midnight shift, e.g.
  - 22:00 to 06:00 (followed by 80 hrs. off)

Two challenges of the 2-2-1 schedule have been documented. The first challenge is that the hours between the second afternoon and the first early morning shift limit the opportunity for sleep and recovery. This was supported by the average sleep reported between these two shifts as being 5.4 hours—similar to that found in the field study by Della Rocco and Nesthus (2005) and similar to actual objective sleep measured in a laboratory study (Cruz, et al., 2003). In 2011, the FAA increased the minimum time between these two shifts from 8 hours to 9 hours. Further increasing this sleep opportunity could potentially help to permit adequate sleep time, as will be discussed below (Section 2.3.6 Challenges Associated with Limited Time-Off Intervals Between Shifts). The second challenge to the 2-2-1 is the sleep opportunity obtained prior to the midnight shift. Only 3.1 hours of sleep was reported prior to the midnight shift on a 2-2-1 schedule in the current sample.

2.3.7 Challenges Associated with Midnight Shifts

Respondents reported that between successive midnight shifts, they slept an average of 5.5 hours. Before midnight shifts during a quick turn-around of 8 or 9 hours, respondents reported sleeping only 3.1 hours. These responses indicate that respondents are incurring a sleep debt that increases the levels of reported fatigue.

Respondents with Counter-Clockwise Rapidly Rotating Midnight (RRM) schedules reported that they got less sleep before *all* shifts than those with Rapidly Rotating (RR) schedules without midnights. Respondents with one or more midnight shifts on their bid schedules scored significantly higher on all three fatigue scales used in the survey when compared to those without midnight shifts. When respondents were asked if they had caught themselves "about to 'doze off'" during work duties in the previous year, those with midnight shifts were more likely to reply "Yes" (71%) than those without midnight shifts (53%).

Respondents indicated that compared to all other shifts, on midnight shifts after very quick turns they felt:

- Least rested at the beginning of their shift
- More likely during their shift to catch themselves about to "doze off" during work duties (closer to "frequently" than "sometimes")
- Least sharp at the end of their shift

2.3.8 Challenges Associated with Limited Time-Off Intervals Between Shifts

About 16% of the time-off intervals between shifts in the bid schedules were only 8-9 hours. About 25% of these time-off intervals were shorter than 11 hours.

2.3.9 Challenges Associated with Early Shifts

The average reported amount of sleep obtained before an early shift (beginning between 06:00 and 07:59) was 6.3 hours. This is below the amount of sleep obtained before shifts that started later in the day, such as afternoon shifts (7.7 hours) or mid-day shifts (7.3 hours), and is consistent with previous research (Della Rocco and Nesthus, 2005; Cruz et al., 2003a).

The reported time slept before an early shift was further reduced to 5.4 hours following a quick turn-around (8-9 hours). Respondents indicated they felt least "sharp" in terms of alertness or memory at the beginning of early shifts after a quick turn-around than at the beginning of any other shift, including midnight shifts after a quick turn-around.

2.3.10 Six-day Constant Schedules

The schedule that controllers reported being least satisfied with was a 6-day constant schedule. These schedules involved working 6 days per week, followed by one day off. Almost two-thirds (64%, 74/114) of these schedules contained midnight shifts. Although the number of personnel that worked a 6-day constant schedule was less than those who worked RRM or RR schedules, 32% of those with these 6-day schedules reported having an operational event in the previous year. This is a higher proportion than those with other types of schedules (average 18%). The proportion of personnel in this sample who reported actually working a 6-day schedule in their last full week of work was about 14%.

Of those working a 6-day schedule in their last full work week, over half (53%, 239/452) also worked at least one midnight shift; 15% (68/452) reported working two or more midnight shifts. Finally, those who actually worked 6-day schedules were not evenly distributed across facility type—over 30% of TRACON personnel in this sample reported working 6-day weeks in the last full week they worked; again, about half also reported having midnight shifts.

Those with the 6-day constant schedule in this sample reported the highest proportion of operational events. They also had the highest ratings of sleepiness on the Epworth Sleepiness Scale. Also, compared to most other schedules, those on the 6-day constant schedules reported awakening more frequently and being unable to sleep when wanting to.

2.3.11.10-hour 4-day Week Schedules

Based on survey responses, the 10-hour 4-day week schedule appeared to be one of the most preferred and least fatiguing schedule types. Approximately 5% of respondents actually worked a 10-hour 4-day week schedule. Respondents reported the most satisfaction with both this schedule and the Straights and Slowly Rotating Days (without midnights) schedules. On the Epworth Sleepiness Scale, the 10-hour 4-day schedule was associated with the lowest sleepiness ratings of all the schedules, including the Straights and Slowly Rotating Days schedule. Respondents reported the fewest problems with being unable to sleep when they wanted to (equal to the Straights & Slowly Rotating Days schedule) and awakening in the middle of their sleep period (equal to the Rapidly Rotating without Midnights schedule).

2.3.12 Staffing Levels Contribute to Difficult Schedules

CPC staffing levels were reported as “not enough” by respondents, and the presence of 6-day schedules may support this issue. When asked how upper level FAA management could reduce controller fatigue, "Increase staffing" was the second most frequent suggestion.

2.3.13 TRACON Schedules

Personnel at TRACONs reported having the least satisfying schedules, most overtime, and highest operational events of all the facilities. About one-third (30.5%) of all personnel at TRACON facilities reported actually working a 6-day schedule, compared to 11.3% at En Route and 11.9% at Tower facilities. Half (50.5%) of the CPCs at TRACONs worked over 40 hours a week compared to 14% in En Route and 21% in Tower facilities. About 33% of CPCs at TRACONs reported having an operational event in the previous year, approximately double the proportion of CPCs at Towers and En Route facilities. Of those TRACON personnel who had an operational event, about 60% considered fatigue to have been a factor.

Compared to CPCs in other facilities, CPCs from TRACONs:

- Reported shorter break times.
- Rated the staffing levels allowing for positions to be rotated for fatigue reduction as least adequate.
- Rated CPC staffing levels as least adequate and were more likely to think that the number of hours worked, overall workload, and traffic complexity was above “about right”.
- Reported the highest rate of catching themselves about to “doze off” during work duties in the last year.
- Scored statistically significantly higher than those from other facilities on the Modified Brief Fatigue Inventory and the Chronic Fatigue Scale.
- Were least satisfied with their schedules.

2.3.14 FLM Schedules

Compared to CPCs and Developmentals, survey results indicated that FLM schedules included a higher number of overtime hours, longer intervals between breaks, and were rated as contributing more to fatigue. About 68% of FLMs and 84% of Operations Managers worked over 40 hours per week compared to 22% of CPCs. The FLMs' bid schedules were similar to those of the CPCs', except the FLMs had a somewhat lower proportion of rapidly rotating schedules with midnight shifts (43% vs. 54%). FLMs rated the time between their breaks as significantly longer than CPCs, and some FLMs indicated they received no breaks at all. FLMs reported being significantly more fatigued than the others on the Epworth Sleepiness Scale. FLMs rated work schedule as contributing to their fatigue more than did CPCs and Developmentals.

2.3.15 Breaks and Rotations

The decline in rated alertness (sharpness) with each half hour on position indicates the value of frequent breaks. About 22% of the respondents reported that their breaks occurred at intervals longer than 1½ hours. CPCs prefer hourly breaks when traffic is busy or workload is high (61.5%) or when providing OJT instruction (44.0%). CPCs prefer breaks every 1 ½ hours when traffic is light or workload is low (40.1%). Having more/longer breaks was the third most frequent suggestion from respondents on what immediate supervisors could do to reduce controller fatigue.

2.3.15.1 Breaks During Low Workload Periods

Most CPCs (76%) felt that more breaks could safely be taken during low workload periods. About 36% of CPCs indicated that these breaks could occur seven or more times per week. The top three suggestions by CPCs on ways that immediate supervisors could reduce fatigue were to staff positions only when necessary, allow naps on breaks, and have more/longer breaks.

2.3.15.2 Timing of Breaks: Low Workload is Fatiguing

Survey respondents indicated that low workload is fatiguing. The most frequent comment regarding breaks was that positions were staffed unnecessarily when traffic was low. The next most frequent comment made by 14.1% of respondents indicated that low workload creates challenges for controllers.

Respondents rated their alertness ("sharpness") as being lower after light traffic than after a heavy push. The difference between light and heavy traffic effects on controller “sharpness” decreased after controllers had been on duty for longer than 1 ½ hours. Respondents also rated their likelihood of having caught themselves about to “doze off" during work duties as higher after light traffic than after a heavy push.

2.3.15.3 Naps during Breaks

Most respondents (82%) reported that brief sleep or naps during breaks would increase their alertness at work.

The shifts on which respondents thought naps were to be of most benefit were early morning and midnight shifts. Those working midnight shifts reported that naps would provide more benefit on midnight shifts than those who did not work on midnight shifts—78% versus 43%.

2.3.15.4 Position Rotations

Position rotations to reduce fatigue were reported as "somewhat adequate" by CPCs.

2.3.16 Sleep Disorders and Other Sleep Problems

Approximately 8% (256/3268) of respondents reported that sleep disorders cause difficulty in their sleeping. Moderate obstructive sleep apnea (OSA) alone has been estimated to affect 7% of all Americans. The proportions for OSA are even higher in a middle-aged American population—9% of women and 24% of men (Young et al.,1993; Lee et al., 2008; Young et al., 2002). Of those in this sample who have a self-described sleep disorder, about 41.6% work rapidly rotating schedules without midnights and a similar proportion work rapidly rotating schedules with midnights (40.8%). About 4% work a 6-day constant schedule.

The rate of reported sleep disorders does not increase with age in this sample as it does in the general population. The proportion of those with self-described sleep disorders rises after age 30 to about 8% and stays fairly constant until ages 51–55, when it reaches 9.9%. The survey also examined whether respondents would take certain prescribed or over-the-counter medications to aid sleep if permitted. About a quarter of the respondents reported they would take over-the-counter or prescription medicine to aid in sleep.

2.3.17 Differences Among Age Groups

Fewer CPCs under the age of 36 worked schedules with midnight shifts than did CPCs age 36 and above (53% vs. 59%). About 27% of those working the 6-day constant schedule were between the ages of 46 and 50.

In the current sample of survey respondents, older workers do not report an increased proportion of operational events even though they work a higher proportion of midnight schedules. The age range of CPCs with the highest proportion of operational events is between 36 and 40 years and decreases thereafter with increasing age.

2.3.18 Training for Fatigue Management

Over half of the CPCs answered "Yes" to the question "Would you like training or information on ways to reduce fatigue?" Those that had midnight shifts in their schedules were more likely to want training or information on ways to reduce fatigue. When asked to indicate how their supervisors could reduce controller fatigue, many respondents suggested that FLMs could take a more active role in monitoring fatigue and could improve their management of controller workload accordingly.

2.3.19 Fatigue Safety Culture

Overall, 18% of respondents indicated that they had a Proximity Event (PE), Operational Deviation (OD), or Operational Error (OE) within the previous year. About 56% of the respondents self-attributed these operational events to fatigue. This is higher than the 5-6% that Della Rocco et al. (2000a) reported in the 1999 survey results. The rise in operational events from the 1999 survey to the present study could not be determined from the questions or responses in the survey.

Although respondents reported that their supervisors supported them in work-related activities, there was less perceived support from supervisors regarding relief for fatigue, such as providing breaks or rotations. Further, respondents reported they were less comfortable asking for such breaks or rotations than asking for assistance for work-related activities.

Even though many controllers did take time off from work due to fatigue at least a few times in the past year, they indicated that they did not feel comfortable doing so. They were even less comfortable telling their supervisor that they had taken time off due to fatigue. Nor were CPCs optimistic that their supervisors would authorize annual leave for controllers to reduce fatigue. An FAA policy has been changed to allow the use of sick or annual leave for fatigue (July 1, 2011 Memorandum of Agreement).

2.3.20 Limitations and Strengths of the Survey

The study sample has limitations. Although the response rate was under 20%, there are many indications that the sample was representative of the overall controller workforce. For example, the proportion of respondents by age and experience was consistent with the overall controller and developmental population. Further, on important schedule measures, such as the amount of sleep before an early shift following a quick turn-around (5.4 hours), the results were consistent with both a field study using objective measurements of sleep (Della Rocco & Nesthus, 2005), a laboratory study (Cruz et al., 2003), and the field study associated with this study. However, it was not established whether there was equal access to computers at different facility types, especially Towers, where the response rate was lowest. There were no returns of paper surveys, which were available at all facilities. It also would have been scientifically worthwhile to obtain information on gender, but to protect respondents' anonymity in smaller facilities, this information was not obtained.

Confirmation of schedule types was challenging. It would have been helpful to confirm that the general properties of the schedules (depicted in Section 2.2.2 Schedules) were representative of the schedules in the general ATC workforce. Although the FAA has the actual schedule data available, classifying the schedule types using the classification scheme from the study was challenging. The vast array of schedule types is indeed difficult to classify, and was one of the most challenging aspects of this study. The schedules are originally designed at individual facilities to cover the particular staffing needs of each facility, which vary greatly.

A strength of the survey was the input on the questions from NATCA and other controllers and the free text input from respondents. Both of these sources conveyed the realities of the work place, helping to clarify the meaning of the ratings and helping to provide the rationale for the findings. All of the comments from respondents were read and considered.

Other strengths of the survey were the detailed description of the respondents’ schedules, the examination of the effects of two new schedule types, and the breakdown of the work force by position and facility. New aspects of the respondents' schedules that were described were: the distribution of shift start times, number and length of between-shift intervals, number of rotations within weeks, number of midnight shifts, and number of shifts worked in a week. The effects of two new schedule types were examined: the constant 6-day schedule and the 10-hour 4-day week schedule (in addition to the rapidly rotating shifts with and without midnights and the shifts without rapid rotations and midnight shifts). Breaking down the work force by position and facility enables focused interventions.

Additional strengths were questions assessing the risk of controller fatigue that respondents' perceived, and questions eliciting their suggestions on how to reduce controller fatigue. Many of their suggestions are reflected in the findings at the end of this report.

3. CONTROLLER ALERTNESS AND FATIGUE MONITORING FIELD STUDY

3.1 OVERVIEW

A field study assessed individual controllers' levels and patterns of sleep, subjective fatigue and alertness ratings, and behavioral measures of cognitive alertness over 14 days while they were engaged in their normal work patterns. Validated measures included wrist activity monitors, sleep/activity logs, and the Psychomotor Vigilance Task (PVT). These data were obtained from a sample of controllers from a targeted set of facilities from April 2010 through December 2010. Data collection ran concurrently with the NASA web-based fatigue survey administered to the entire air traffic control population.

This study was designed to determine whether patterns of work schedule-related sleep and alertness were similar to those found in studies conducted by CAMI more than a decade earlier. The present study was designed for comparability to these earlier findings, which are described in section 1.3 of this report. These findings describe the relationships between a number of variables that define the shifts and schedules that controllers work, the amount, quality and patterns of sleep obtained on those various schedules, and the associated levels of alertness or fatigue experienced by the controllers.

3.2 METHOD

3.2.1 Facility Selection

Initially, 14 facilities were selected to participate in the field study, the goal being a sample of 104 participants from four En Route facilities, 52 from four TRACONs and 52 from six ATC Towers. The NASA research team worked with the FAA and the Article 55 Fatigue Risk Management Work Group to identify suitable facilities. Several criteria guided this selection:

- 24-hour operations, thus including midnight shifts
- High traffic levels based on the FAA's facility ratings, (which range from 1 to 12)
- Varying levels of CPC staffing in relation to the FAA's target staffing levels (FAA, 2009). Note: Low levels of CPC staffing were found to be associated with high ratios of developmentals to CPCs, a factor that could affect workload and stress of the CPCs (DOT OIG, 2009)

In order to manage time and costs associated with research team travel to facilities for data collection, clusters of qualifying facilities in the same geographic area that included a Center, a TRACON and at least one Tower were sought.

At the end of the initial data collection period (which lasted from April 15, 2010, through August 28, 2010), it became apparent that our recruitment and data collection efforts at the original 14 facilities were falling short. Some controllers who signed up to participate were not available to be trained; others went through the training, but then either dropped out of the study or provided only partial data. By the end of August (the initial completion date), a satisfactory level of participation with complete data, with completion defined as 9 work days (out of 14) with associated sleep log, actigraphy and PVT data was not achieved. Using this criterion, data completion rates by August 28, 2010 were 77% from En Route Centers, 42% from TRACONs and 27% from Towers.[9] In order to achieve sufficient power to

[9] These differences in participation rates reflected a bias in the data collection process. Because the new En Route Automation Modernization (ERAM) technology was scheduled for implementation in the summer of 2010 at a number of facilities included in our data collection plan, our initial data collection effort focused on En Route Centers.

detect significant differences between facility types, additional facilities were determined to be needed: one En Route Center, six TRACONs, and ten towers.

In consultation with the FAA and the Article 55 Fatigue Risk Management Work Group, a second wave of facilities meeting the original criteria was identified. The full set of participating facilities is listed in Table 3-1, along with the number trained from each. Table 3-1 provides information on the facility characteristics: staffing levels, ratios of CPCs to developmentals, ratio of CPC staffing to the minimal staffing levels, and traffic levels (FAA, 2009).

It should be noted that it was deemed not practical to go back to facilities that had already participated to try to solicit more volunteers after the initial August 28, 2010 date. Some of those facilities had adjusted local schedules to permit data collection, and asking them to do so again would have placed a significant burden on them. In other cases, enthusiasm for participating in the study was lacking on the part of local FAA management or NATCA representative; trying to solicit more volunteers was not thought to be productive under those circumstances. In still other cases there simply were not enough CPCs who met all of our criteria, including working midnight shifts.

Table 3-1. ATC Facility Staffing Levels and Traffic Levels for Participating En Route Centers, TRACONS and Air Traffic Control Towers

Facility	Number of CPCs	Number of Develop-mentals	CPC/ Develop-mental Ratio	Minimal Defined Staffing Level-MDSL	Staffing Ratio: CPC/MDSL	Traffic Level
En Route Centers						
ZAU	338	82	4.12	286	1.18	12
ZDC	262	70	3.74	270	0.97	12
ZDV	243	67	3.63	243	1.00	10
ZNY	232	90	2.58	242	0.96	12
ZOA	176	56	3.14	195	0.90	11
Mean			3.44		1.00	
TRACONs						
C90	71	16	4.44	85	0.84	12
D01	36	16	2.25	58	0.62	11
D10	56	17	3.29	74	0.76	12
I90	62	5	12.40	68	0.91	12
L30	25	9	2.78	42	0.60	11
N90	174	48	3.63	180	0.97	12
NCT	132	28	4.71	144	0.92	12
PCT	136	35	3.89	147	0.93	12
PHL*	66	21	3.14	73	0.90	12
P50	45	9	5.00	50	0.90	11
SCT	163	44	3.70	196	0.83	12
Mean			4.48		0.83	
Air Traffic Control Towers						
BWI	27	0	0.00	20	1.35	9
DEN	31	5	6.20	32	0.97	12
DFW	41	12	3.42	41	1.00	12
IAD	34	6	5.67	28	1.21	11
IAH	30	6	5.00	32	0.94	12
JFK	24	9	2.67	29	0.83	10
LAS	26	7	3.71	34	0.76	11
OAK	22	4	5.50	18	1.22	8
ORD	48	5	9.60	52	0.92	12
PDX	22	2	11.00	20	1.10	8
PHX	29	8	3.63	30	0.97	11
SEA	27	0	0.00	23	1.17	9
SFO	26	2	13.00	25	1.04	9
SLC	30	2	15.00	25	1.20	10
Mean			6.42		0.94	

** PHL is a Combined TRACON and Tower, but all participants were functioning as TRACON controllers during the study period.*

3.2.2 Participants

The objective data collection effort aimed for a sample of 208 active controllers (104 from En Route Centers, 52 from TRACONs and 52 from Air Traffic Control Towers), a number that would yield sufficient power for between-subjects statistical comparisons and modeling, based on a power analysis (Cohen, 1992). Study volunteers had to meet the following criteria:

- Work a schedule that included at least 1 midnight shift during the 14-day study period
- Work at least 9 shifts during the 14-day study period (not be on leave)
- Actively control traffic (excluded supervisors)
- Be a fully Certified Professional Controller (CPC) and have at least one year of experience as a CPC (excluded developmentals)
- Be at least one year from planned or mandatory retirement age
- Not have an untreated sleep disorder

All participants were asked to participate in the second phase of the study, to be conducted approximately two years after initial data collection, in order to evaluate the impact of the controller Fatigue Risk Management System (FRMS) the FAA planned to put into place following completion of this study.

3.2.2.1 Recruitment

The FAA and NATCA made initial contact with each participating facility to share information about the purpose of the study and procedures to be followed. Posters advertising the study were sent to those facilities. Prior to visiting each facility, NASA researchers contacted the facility management and NATCA representatives by email to enlist their support in recruiting participants and provided them with a study recruitment letter to share with their controllers. Participants volunteered using the website http://nasasurvey.us (see Appendix E). The data submitted during signup were accessible only by the NASA research team.

3.2.2.2 Random Participant Selection

A procedure was developed to assure random selection of study participants in the event that a greater number of controllers from a facility volunteered to participate than could be accommodated. However, this procedure was not utilized because no facility yielded excess volunteers.

Target sample sizes and the number of study participants trained in the experimental procedures from each participating facility are shown in Table 3-2.

Table 3-2. Number of Target and Trained Participants from each Participating Facility

En Route			TRACON			Tower		
Facility ID	Target n	Trained n	Facility ID	Target n	Trained n	Facility ID	Target n	Trained n
ZAU	26	27	C90 [a]	8	2	BWI	8	7
ZDC	26	26	D01 [a]	9	2	DEN	7	5
ZDV	26	27	D10 [a]	9	8	DFW	9	3
ZNY	26	26	I90 [a]	9	7	IAD	7	4
ZOA	26	35	L30 [a]	7	5	IAH	6	2
			N90 [b]	15	19	JFK	6	7
			NCT [b]	19	19	LAS	6	2
			P50 [a]	1	1	OAK	6	6
			PCT [b]	14	6	ORD	9	7
			PHL [b, c]	10	7	PDX	6	6
			SCT [b]	15	18	PHX	5	5
						SEA	8	8
						SFO	6	6
						SLC	6	6
Total	130	141	*Total*	116	94	*Total*	107	74
Overall Total							353	309

a. TRACON, RAPCON or CERAP
b. Combined TRACON/Tower
c. All participants from PHL were working as TRACON controllers even though it was a combined facility.

3.2.2.3 Participant Privacy and Human Subjects Protection

This study was reviewed and approved by NASA's Institutional Review Board for the Protection of Human Subjects, protocol #HRII-09-10 dated June 30, 2009, and HRII-10-24 dated July 27, 2010.

Each participant was randomly assigned a unique ID number that was associated with all of her/his data in order to protect the participant's privacy. It is not possible to link data (either objective field data or survey responses) to an individual's name. Participation in the study required a signed consent form (see Appendix B), which was kept separate from study data and does not include the unique ID number. To further ensure anonymity, all data are reported at the aggregate level.

As another safeguard, participants were informed that in the unlikely event of an operational event during the data collection period, all relevant data would be purged immediately to ensure that identifying information or responses could not be linked to any individual. No such event occurred for the duration of the study.

Participants were advised that participation in the study was voluntary and that they had the right to withdraw from the study at any time for any reason. They were not compensated for participation in the study, as most of the study activities were accomplished during working hours.

3.2.2.4 Participant Demographics

Participant breakdowns by age and years of experience shown for each facility type are in Table 3-3 and Table 3-4, respectively. Note that some participants chose not to provide their demographic data.

Table 3-3. Proportion and Number of Participants in Different Age Categories

	Overall		En Route		TRACON		Tower	
Age	Proportion of Participants	n	Proportion of Participants	n	Proportion of Participants	n	Proportion of Participants	n
25 or under	3.57%	8	2.59%	3	3.70%	2	5.56%	3
26-30	14.29%	32	15.52%	18	9.26%	5	16.67%	9
31-35	8.93%	20	10.34%	12	9.26%	5	5.56%	3
36-40	12.95%	29	11.21%	13	16.67%	9	12.96%	7
41-45	21.88%	49	19.83%	23	22.22%	12	25.93%	14
46-50	29.02%	65	31.90%	37	25.93%	14	25.93%	14
51-55	8.93%	20	7.76%	9	12.96%	7	7.41%	4
56+	0.45%	1	0.86%	1	0.00%	0	0.00%	0
Total	100.00%	224	100.00%	116	100.00%	54	100.00%	54
Missing		27		7		16		4
Total		251		123		70		58

Table 3-4. Proportion and Number of Participants' Total Years of Professional Experience with ATC (Including the Military)

	Overall		En Route		TRACON		Tower	
Years of Experience	Proportion of Participants	n	Proportion of Participants	n	Proportion of Participants	n	Proportion of Participants	n
< 1	0.00%	0	0.00%	0	0.00%	0	0.00%	0
1-4	9.25%	21	10.26%	12	3.57%	2	12.96%	7
5-9	10.13%	23	11.11%	13	8.93%	5	9.26%	5
10-19	29.07%	66	26.50%	31	30.36%	17	33.33%	18
20-29	46.70%	106	50.43%	59	48.21%	27	37.04%	20
30+	4.85%	11	1.71%	2	8.93%	5	7.41%	4
Total	100.00%	227	100.00%	117	100.00%	56	100.00%	54
Missing		24		6		14		4
Total		251		123		70		58

3.2.2.5 Participant Work Schedules

Every effort was made to fit the schedules worked by controllers in the present field study to those described in our accompanying Fatigue Factors Survey and those defined by Della Rocco, et al. (2000a). However, the comparability was limited by the nature of the present study. First, controllers with midnight shifts were actively recruited. This automatically eliminated the straight shift without midnights (SS) and significantly reduced several other schedule types, such as the counterclockwise, rapidly rotating, no-midnights (RR) schedule or the 10-hour 4-day schedule without midnight shifts. Second, participants in the present study could have begun data collection on any day during their normal work week, not just on the first day, i.e., on days 2 through 5 (or 6). Consequently, it was not unusual for the initial sequence of days to consist of a partial week (e.g., two or three work shifts), followed by regular days off (RDO), then a full 5-day work week, RDO, and then end with another partial week. Thus, 14 days of data collection might yield, for example, three work days (WD), two RDO, five work days, two RDO and two work days. This picture was further complicated when an unanticipated day off occurred in the middle of a work week, yielding a sequence such as the following:

3 WD, 2 RDO, 2 WD, 1 RDO, 3 WD, 1 RDO, 2 WD = 14 days

Because of variability in start dates and completeness of data (e.g., actigraphy, PVT and sleep/activity logs), the nominal 14 days of data collection could yield one full 5-day work week plus two fragments, or two full work weeks, or no full work weeks. This mixture of partial and complete work weeks created uncertainty in characterizing the participants' work schedules, which was essential for classifying them prior to analysis. Bid schedules were obtained only from participants who signed up to participate on the NASA website. A description of their bid schedule was requested on the sign-up page (see Appendix E). Many other participants signed up while the NASA experimenters were at their facility to conduct training. Volunteers were asked to sign up on the web so that access to their full demographic and schedule information was available, but not all complied. In addition, the schedules worked did not always conform to the bid schedules. Thus, comparing present schedules with those of Della Rocco, et al. (2000) was a challenge. Obtaining the participants' actual recorded work schedules from the FAA's Business Objects database for the duration of their study period, plus the week prior to and two days following their study period, considerably reduced the uncertainty concerning regular bid schedules.

For the analyses relating both sleep patterns and measured alertness to work schedules, only 5-day and 6-day work weeks were characterized. Using the FAA's business objects (BO) data, the schedules worked by each participant during the study period were classified into several categories. These categories correspond to those used in our analysis of the survey data, as well as those reported in Della Rocco, et al. (2000a).

3.2.3 Procedure

Over the nominal 14-day study period[10] at each facility, each participant was required to:

- Wear an actigraphy monitor that recorded active and sleep periods over a 24-hour cycle
- Keep a daily sleep/activity log
- Self-administer an objective alertness measure, the Psychomotor Vigilance Task (PVT), three times during each work shift

[10] Each participant's data collection period was 14 days. However, some participants provided more than 14 days of data. Because not all participants at a facility were trained at the same time, the duration of training could extend over four days with individual start dates staggered over the four days. The experimenters did not pick up the equipment from a facility until after the last-trained participant had completed 14 days. Hence, earlier trained participants could, at their discretion, provide up to four extra days of data.

3.2.3.1 Activity Monitors

Activity monitors, or actigraphs, track sleep and wake periods through an accelerometer that is sensitive to movement. Participants continuously wore an actigraph the size and shape of a small wristwatch on their non-dominant wrist to record sleep and wake periods for 24 hours per day. These activity monitors were removed only during showers, swimming, or other activities likely to damage the watch. Figures 3-2a and 3-2b show two actigraph models compared to digital wristwatches. In Figure 3-2a the activity monitor (to the right of the digital watch) is manufactured by MiniMitter, model Actiwatch-64; in Figure 3-2b the monitor (with red cover) is manufactured by ActiGraph, model GT3X Ambulatory Monitoring System.

Figure 3-1a. Digital watch (L) and MiniMitter Actiwatch-60 (R)

Figure 3-1b. ActiGraph GT3X (L) and digital watch (R)

In order to establish the comparability of the two models of watches, prior to the beginning of the study five members of the NASA research team wore one or more pairs of actigraph watches, one of each model, for a period of a week. Recorded sleep timing, duration and efficiency were compared across the two models. No significant differences across models were found. Use of the two models did not vary systematically across facility types or schedules. In many cases, both models were used within the same facility, especially en route centers, where data were collected simultaneously from a large number of participants.

3.2.3.2 Sleep/Activity Log

A daily log was used to record significant events during each day of the study. Based on the logs developed initially for studies of fatigue in airline pilots (Gander, Myhre, Graeber, Andersen, & Lauber, 1989) and for prior CAMI field studies with controllers (for a summary of this work see Della Rocco & Nesthus, 2005), the log included a number of separate entries to be filled out across the day. Participants recorded the times at which they went to sleep and awakened from their main sleep periods and naps, started and ended work, and took the PVT during work hours. They rated their alertness/sleepiness levels upon awakening and after taking each PVT using the Stanford Sleepiness Scale (Hoddes, Zarcone, Smythe, Phillips & Dement, 1973). They also rated the level of workload they experienced during the work period prior to each PVT administration. Following are the codes used in the sleep/activity logs:

ACTIVITY Codes

S - Time to Sleep (including main sleep and naps)
A - Time Awake from main sleep or nap
T - PVT Test Time
W - Began Work

E - Ended Work
O - Actiwatch Off (shower, swimming, etc.)

ALERTNESS/SLEEPINESS Rating

1 - Feel active and vital; alert; wide awake
2 - Functioning at a high level, but not at peak; able to concentrate
3 - Relaxed; awake; not at full alertness; responsive
4 - A little foggy; not at peak; let down
5 - Fogginess; beginning to lose interest in remaining awake; slowed down
6 - Sleepiness; prefer to be lying down; fighting sleep; woozy
7 - Almost in reverie; sleep onset soon; lost struggle to remain awake

WORKLOAD Rating ***(****Refers to the work period immediately preceding each PVT)*

1-----2-----3-----4-----5-----6-----7
Very Low — Moderate — Very High

Figure 3-2 is an example of a completed Sleep/Activity Log for one 24-hour period. Note that the person was awake at midnight (0000) when the log began, went to sleep at 0130, and awoke at 0930. Upon awakening, the person reported being fully rested and wide awake (rating of 1 in the Fatigue row at 0930). The actiwatch was taken off at 1000 (perhaps for a shower). At the beginning of the work shift at 1300, the first PVT was taken; the participant rated sleepiness at that point as 1 (= low, or wide awake) and began to work at 1330. The second PVT was taken at 1700, at which point sleepiness was rated as 2; workload during the prior work period was rated as 3 (slightly below average). The third PVT was taken at 2100 when sleepiness was rated as 4 and prior workload at 5, or slightly above average. The work shift ended at 2230.

DAY 1	**0000**		**0100**		**0200**		**0300**		**0400**		**0500**		**0600**		**0700**		**0800**		**0900**		**1000**		**1100**	
Activity				**S**																**A**	**O**			
Fatigue																				**1**				
Workload																								

DAY 1	**1200**		**1300**		**1400**		**1500**		**1600**		**1700**		**1800**		**1900**		**2000**		**2100**		**2200**		**2300**	
Activity			**T**	**W**							**T**								**T**			**E**		
Fatigue			**1**								**2**								**4**					
Workload											**3**								**5**					

Figure 3-2. Sleep-Activity Log filled out for 24-hours.

3.2.3.3 Psychomotor Vigilance Task

Participants took a 5-minute behavioral test of mental alertness three times during each work shift during the study period. The Psychomotor Vigilance Task (PVT) is a simple reaction time task, which was administered on a handheld PDA (a Palm Centro with phone capability disabled). Software developed by researchers at the Walter Reed Army Institute for Research (WRAIR) for administering the PVT on a PDA was used (Thorne, Johnson, Redmond, Sing, Belenky & Shapiro, 2005). Participants were instructed to press a designated response button on the device as quickly as possible when a stimulus (bull's-eye) appeared on the screen (See Figure 3-3); either the right or the left response button was used, depending on the participant's handedness. Reaction times in hundredths of a second were visually displayed in the target for each trial. Inter-stimulus intervals varied randomly from 1 second to 10 seconds.

The first PVT was taken at the beginning of each work shift. The second PVT was taken after a break period as close to the middle of the shift as possible. The third PVT was taken after the final break, ideally 1 hour or so before the end of the work shift, in order to assess participants' alertness going into their final segment on duty.

It should be noted that the PVT was originally validated as a 10-minute test (Dinges & Powell, 1985), though the sensitivity of the PVT is increased by using a longer task duration (Dinges & Weaver, 2003; Dorrian, Rogers & Dinges, 2005). The greater sensitivity is useful when dealing with mild to moderate levels of sleepiness. However, given that the PVT was to be administered during working hours, FAA managers expressed concern about the cumulative amount of time required for data collection. Hence, the 5-minute version of the PVT, which had been validated by several groups in the US and Australia (Lamond, Jay, Dorrian, Ferguson, Roach, & Dawson, 2008; Loh, Lamond, Dorrian, Roach & Dawson, 2004; Thorne, Johnson, Redmond, Sing, Belenky & Shapiro, 2005) was chosen. Most recently, Dinges and his colleagues have validated a 3-minute PVT (Basner, Mollicone & Dinges, 2011; Basner & Rubenstein, 2011), but this was not available when our study was begun. One concern with using a briefer test is that performance degradation may take time to emerge, especially lapses (responses slower than 500 msec). However, given prior research reports based on the 5-minute version, it was deemed an acceptable compromise between test duration and sensitivity.

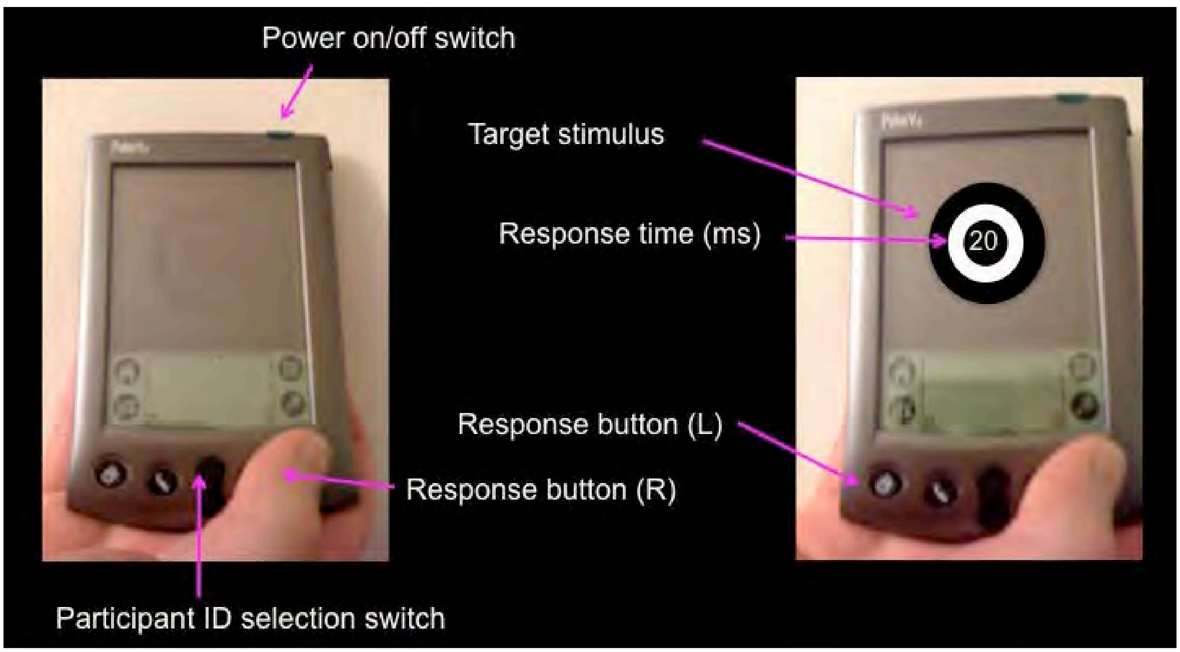

Figure 3-3. Psychomotor Vigilance Task (PVT) on a Palm Centro PDA.

In summary, each participant provided 14 days of data that comprised the following measures:

- *Actigraphy Data*: Continuous 24-hour recordings over 14 days, except when showering or engaging in potentially damaging activities. Sleep duration, sleep efficiency and sleep timing were recorded.
- Sleep and Activity Logs: Daily records indicating sleep times, wake times, and work hours, as well as times at which the PVT was taken.
- Subjective Sleepiness and Workload Ratings: Ratings of how sleepy or alert participants felt upon awakening from each sleep period and when taking the PVT. Perceived workload was rated for the work period immediately prior to each PVT administration.
- Psychomotor Vigilance Task (PVT): Taken three times during each work shift, at the beginning, middle and end, typically over 10 work days within the 14-day data collection period.

3.2.3.4 Participant Training

In preparation for data collection at each facility, two members of the NASA research team were on site for up to four days to provide an introduction to the study and training in data collection procedures. Study participants met with the NASA team at the beginning of a shift, either individually or in groups of up to four controllers. Training sessions occurred any time during the 24-hour day depending on when participants' shifts began.

The study introduction and training took approximately 30 minutes and covered:

- Actigraph care and use
- How to fill out the sleep/activity log
- Psychomotor Vigilance Task (PVT) administration
- Web-based survey instructions and PIN
- Participant confidentiality and human subjects protection

A graphic representation of the data collection schedule for one participant over the 14-day study period is shown in Figure 3-4.

Throughout the training, the procedures undertaken to assure confidentiality of individual data and the use of randomly assigned personal ID numbers on all data, including the sleep/activity logs and the self-administered PVT (on the PDA), were emphasized. Actigraph watches were linked to participants' ID codes through their serial numbers.

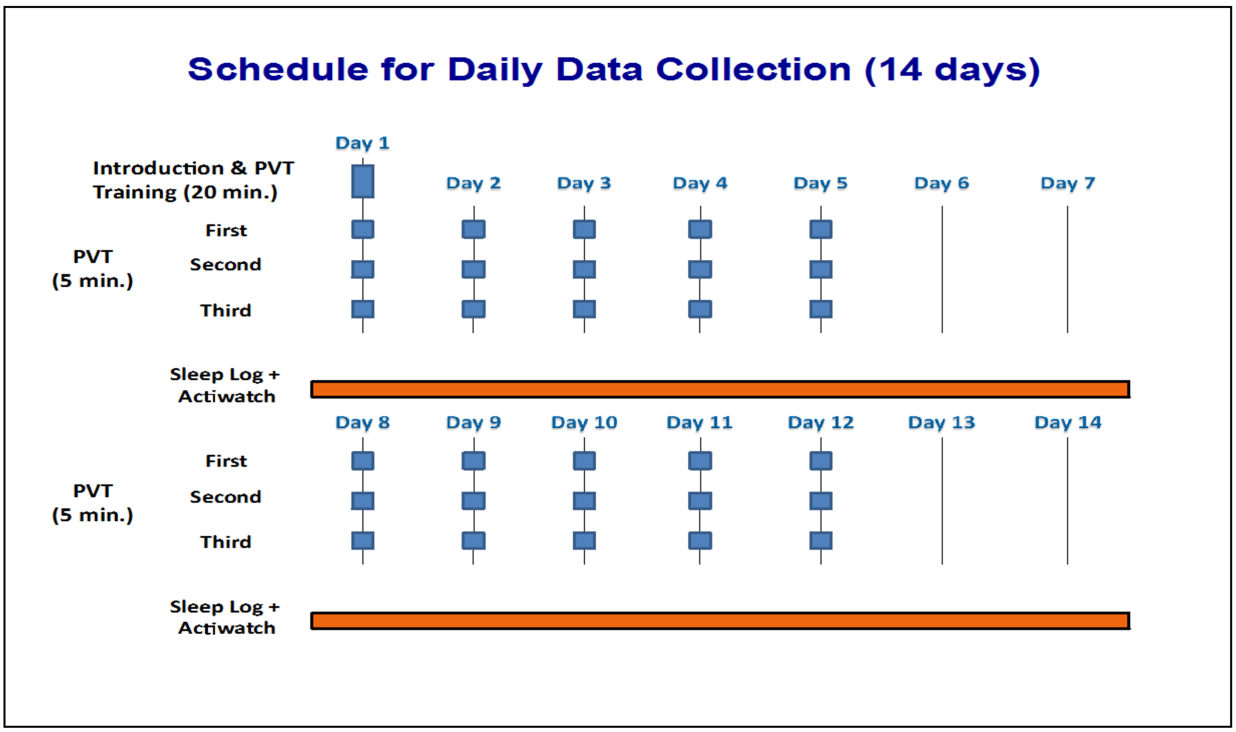

Figure 3-4. Schedule for daily data collection over the 14 days of the study period.

Day 1 included a training period. This schedule shows an idealized work week, with five sequential workdays followed by two regular days off (RDO). In reality, some participants were trained on the second, third, fourth or fifth shift of a work week, which meant that the first and last weeks of data collection were broken up. The term 'day' refers to shift, acknowledging that midnight shifts in fact often began on the same day as the prior shift.

Participants were provided with a take-home user guide that summarized all of the information contained in the training for reference throughout the study; a laminated copy of the procedures was also available at the facility for use during on-shift data collection (i.e., when taking the PVT and filling out the activity logs). The personal instruction sheet is illustrated in Appendix C. NASA scientists were available on site during training or by phone 24/7 to answer questions as needed.

Participants were instructed where to return their actiwatches and sleep logs at the end of the study period. A member of the NASA team picked up all data collection instruments (i.e., actigraphs, Palm Centros, logs) after the last participant had completed all days of data collection.

3.2.4 Data Review and Pre-processing

Each participant's data were reviewed to determine completeness over the 14 days of data collection. By 'complete' it is meant that the participant worked at least 9 days, wore the actigraph watch during that period, filled out the sleep-activity log, and took three PVTs during each work shift. Participants for whom at least 9 days of complete data was collected were included in the overall analyses. Multilevel modeling requires sufficient power to assess contributions of variables at various levels; to maximize power inherent in the data set, participants who provided at least five days of complete data out of the 14 days were also included in overall analyses. A second criterion was used to determine inclusion: If a participant's data were complete for at least 5 work days and the five days constituted an entire work week unbroken by any regular days off (RDO), their data were included as well in the analyses that involved shift schedules.

Sleep/Activity Logs. Data from each participant's sleep/activity log were used to determine three critical aspects of a person's day: the times at which the controller went to sleep and woke up, began and ended work, and self-administered the PVT (three times during a work shift). Sleep/wake times from the logs were essential for aligning the actigraphy data properly. Work shift start and end times were needed to establish the schedule each participant was working over the course of the 14 days, the type of shift worked on each day, regular days off, and other days off (e.g., sick days). The shift start and end times also served to verify the times at which the PVT was taken (i.e., to make sure that the reported PVT times aligned with actual work periods).

Participants occasionally neglected to make an entry in their activity logs, which caused difficulties in alignment or in establishing their actual worked schedules. Most common was failure to note time completing work. The next most common omission was skipping over one or more days off in the log. Given that the number of days off varied significantly, this omission increased the uncertainty of alignment of the work days with the actiwatch data.

The FAA provided a solution to this problem.[11] Actual shift start and end times were obtained for all participants in the study, along with five days prior to the participant's 14-day data collection period and two days after (21 days, or three weeks). This longer span made it possible to establish bid schedules and those actually worked, which was impossible to determine from the logs when participation began in the middle of a week, i.e., when a participant's first day of data collection was the third or fourth or fifth day of a work week. When participants signed up on the web to participate in the study, they were asked to provide the bid schedules they expected to work at the time of data collection at their facility. However, not all did so. Even when schedules were provided, they frequently changed due to overtime, family issues, or other unknown causes. Hence, incomplete data concerning shift schedules was

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[11] The NASA research team is grateful for the assistance of the FAA's Fatigue Risk Management Office, NATCA, and the anonymous contractor in developing and executing the procedure to obtain study participants' actual work schedules.

frequently encountered, a problem solved by obtaining actual schedules worked from the FAA's Business Objects (BO) database.

The following procedure for obtaining this schedule information was reviewed and approved by NATCA. Participant confidentiality was maintained by transmitting the request to a contractor who was made a member of the NASA research team for this purpose, thereby extending the NASA Human Research Institutional Review Board (HRIRB) guidelines and requirements to that individual. The person signed a letter of agreement, indicating a commitment to comply with the HRIRB guidelines for the protection of human subjects.

A *new* ID number was randomly assigned to each individual (different from the one used to identify the participant's data). These new IDs were paired with the participants' names and the date range for the specified work periods and sent to the contractor. The contractor then extracted the daily work schedule data for each individual from the FAA's Business Objects database and returned the data file to NASA using only the new participant ID numbers. The new IDs were converted back to the original ID numbers and entered the schedules into each participant's data file. Documents linking the individual names and ID numbers were then destroyed.

Actigraphy Data. The 14 continuous days of actigraphy recordings were downloaded to a computer for permanent storage immediately following the data collection period (after equipment pick-up by the experimenter at the facility). The downloaded data had to be visually inspected for gaps. Then they were aligned with the sleep/activity log information to establish the time at which the participant went to sleep and awoke. A full list of all the available sleep parameters provided by the actiwatch is provided in Appendix D. Only a subset of these was used to establish the total sleep time (TST) for each major sleep period and naps, as well as sleep efficiency.

An example of the preprocessing of the actigraph data, prior to analysis, is shown in the bottom half of Figure 3-5. The corresponding sleep and activity log is in the top half, illustrating the correspondence between times listed in the log and reflected in the actigraphy.

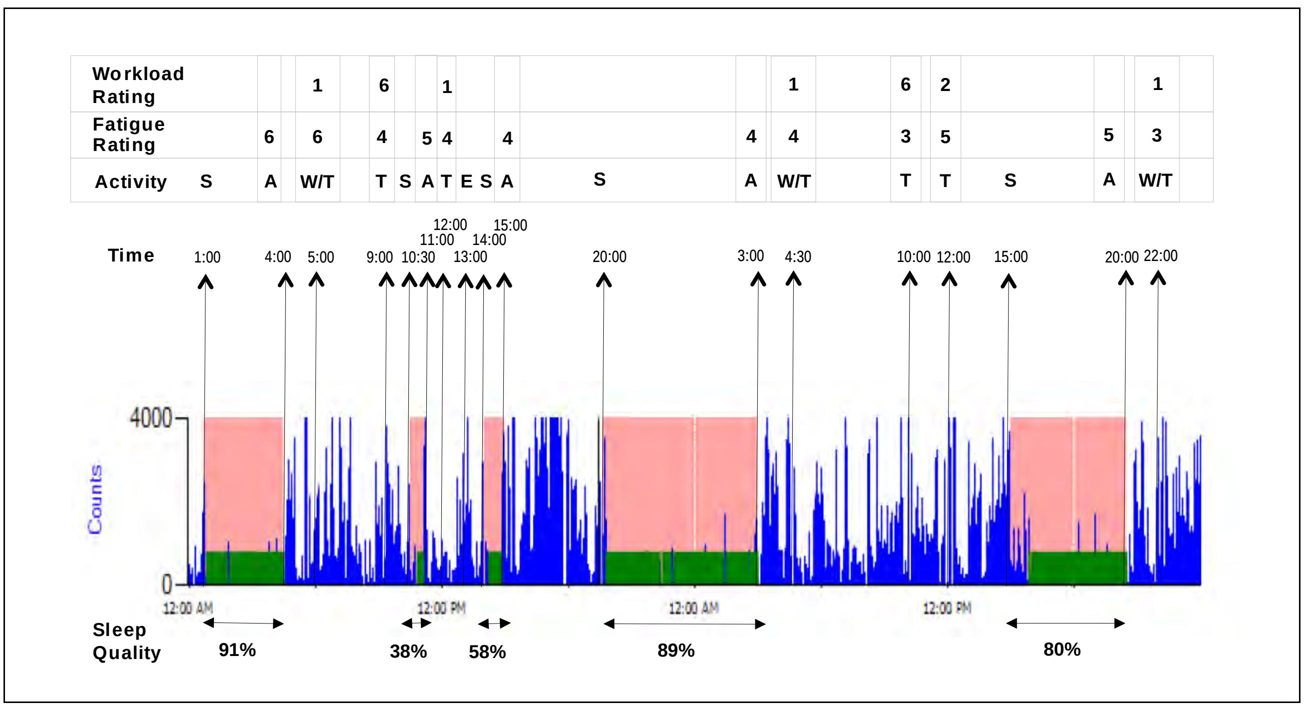

Figure 3-5. Sleep/activity log and actigraphy data over 48 hours (n = 1).

The pink blocks represent assumed sleep and the green blocks are actual sleep, defined as "the amount of sleep as determined by the algorithm and equivalent to assumed sleep minus wake time." Sleep efficiency is a measure calculated as the ratio of actual sleep time to time in bed, or the *proportion of sleep in the episode actually filled by sleep. Normal sleep efficiency is at least 85% (i.e., asleep 85% of time in bed). Blue lines indicate activity level measured in counts of wrist movements).*

PVT Data. Each participant's PVT data were downloaded to a storage computer from the PDA device on which they were collected and then aligned with times of day as noted on the sleep/activity log. The PDA automatically recorded the time of day at which each test was taken, thus providing a check on the self-reported PVT administration times entered in participants' log books.

The PVT software records reaction time to each stimulus in milliseconds, which serves as the foundation for two measures of behavioral alertness: response speed and lapses. Response speed is the reciprocal of the reaction time, or 1/RT. Lapses were defined as reaction times slower than 500 msec. The software provides a count of lapses based on specification of the cut-off response time. These two measures have been identified as the most appropriate and sensitive to use in studies of fatigue (Basner & Dinges, 2011).

3.2.4.1 Analysis of Objective Sleep, Fatigue and Alertness Data

Data for the field study were analyzed primarily through multilevel modeling because of the nested hierarchical structure of the database. The data structure is illustrated in Figure 3-6.

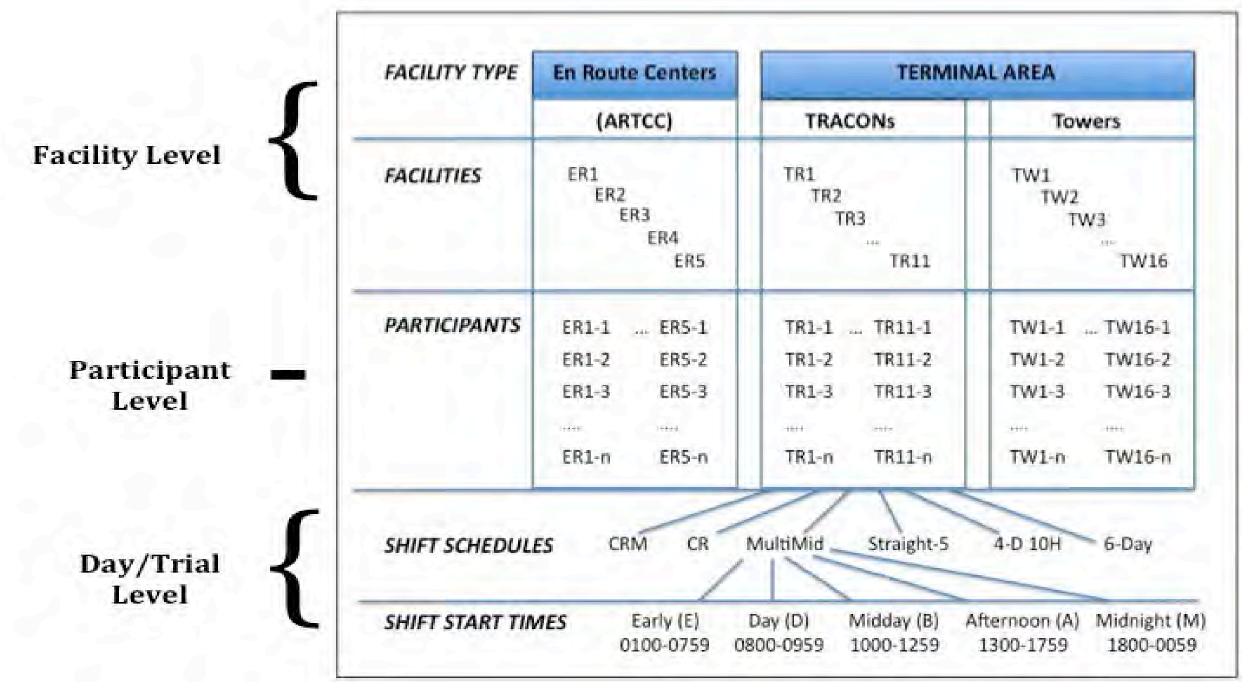

Figure 3-6. Hierarchical structure of the field study data.

Level 1 is the day and trial level. PVT, subjective fatigue, and workload measures at three time points during each work shift are characterized at this level, along with individual work shift types and weekly schedules. Level 2 is the participant level and includes demographic variables (e.g., age, gender and years of experience as a controller) specific to each participant. Level 3 is the facility level, including features specific to each facility used in the analyses: type of ATC facility, traffic level, staffing level, staffing ratio, and ratio of CPCs to developmentals.

Often when such nested structures exist, researchers may be tempted to average the data at a lower level (e.g., across days) or ignore the nested structure of the data. This leads to either loss of information or incorrect partitioning of variability associated with different variables. For example, individual differences are considered to account for large variance among sleep durations and fatigue associated with sleep deprivation. Such individual differences would be disregarded in analyses that do not account for the nested structure. Multilevel modeling is a confirmatory statistical technique where researchers create and test a series of hierarchical linear regression models based on theories and available evidence. Linear regression in general is an approach to modeling the relationship between a dependent variable and one or more explanatory variables or predictors. A relationship is modeled by examining the covariation or correlation between the dependent variable and the predictors. Multilevel modeling allows for partitioning of variance in the data among different levels so that correct analyses can be performed. This is important because a relationship cannot exist between factors where at least one is constant (e.g., predicting the work schedule that minimizes fatigue if everyone sampled has the same level of fatigue). A simple linear regression assumes that factors at different levels are constant. Additionally, multilevel modeling allows for parameters at higher level to vary (e.g., sleep duration-response speed relationship to vary among participants), thus, enabling researchers to understand better the nature of individual differences and other higher level variables.

The goal of our analyses was to determine the relationships between work schedules, quantitative and qualitative measures of sleep, and measured alertness. Specifically, the data was examined to determine the following:

- Whether higher levels of reported fatigue and measured alertness decrements are associated with specific work shifts and weekly work schedules (i.e., midnight shifts, rapidly rotating shifts).
- Whether the relationships between work schedules and resulting fatigue and alertness are mediated by quantity of sleep.
- Whether the relationships between schedule types, sleep and alertness are moderated by controller demographics or facility features.

Several strategies were used to test these relationships.

Step 1. Individual Level Analyses: The FAA's Business Objects (BO) data were used to establish the schedule each participant worked over the 14-day test period and to determine the timing and duration of time off, which created opportunities for restorative sleep. Gaps in a participant's BO schedule data were filled using his or her sleep/activity log. It was especially important to determine accurately the time off between shifts (e.g., 8 hrs, 9 hrs, 10 hrs) in a rotating schedule. Second, the duration, timing and efficiency of sleep were determined from the actigraph data based on guidelines for identifying sleep start and end times provided in the user manuals. Third, subjective reports of alertness/sleepiness upon awakening were obtained from self-report ratings on the sleep/activity logs. Fourth, PVT data (both response speed and lapses) served as behavioral measures of cognitive alertness. These four types of data were input to multilevel modeling to establish causal relationships between various schedule factors, sleep patterns and resulting fatigue and alertness.

Step 2. Secondary analyses were conducted to determine:

- Differences in alertness across a work shift (beginning, middle, end of shift), and as a function of perceived workload during the work period prior to each PVT administration.
- The relationships between amount of time off between shifts, amount and timing of sleep, and measured alertness based on the PVT.

Step 3. Moderator Analyses: Moderator analyses were conducted to determine whether the findings from the initial analyses held across all participant demographics and facility features. Demographic variables included age, gender and years of experience in ATC. Facility variables included facility type (En Route Centers, TRACONS and Towers), traffic level, staffing level and ratios of CPCs to developmental controllers.

3.2.4.2 Aligning Field Study Data with Survey Data

Participants in the field study were asked to fill out the web-based fatigue factors survey (if they had not already done so) and to include their participant ID number in order to align their survey data with their objective data while keeping their identity protected. In the event that they had completed the survey prior to the objective data collection, participants were requested to provide the personal ID number they had entered on the survey. Some participants had not entered an ID and some had forgotten their ID, so it was not possible to align those participants' two data sources.

After establishing the relationships between work schedules, sleep patterns, and controller alertness, the surveys were examined for those controllers who completed both data sets (survey and field study) to enrich our understanding of the patterns of field study findings.

3.3 RESULTS

3.3.1 Database Description

3.3.1.1 Activity Log Data

Altogether, 293 participants completed activity logs. Out of 293, 19 were eliminated because their work schedules during the study period did not consist of 5 or more work shifts. However, the FAA's BO database enabled the inclusion of 12 other participants who worked 5 or more shifts and otherwise would have been lost to the analyses due to missing log data. The breakdown of number of shifts worked during the entire study period for the resulting 286 participants is displayed in Table 3-5. Note that although the modal number (29.7%) of participants reported working 11 days within the14-day participation period, over 21% worked more than 11 days in the 2-week period, presumably due to scheduled overtime. The majority of the 286 participants (*n* = 165, 57.7%) participated for longer than 14 days.

Table 3-5. Number and Proportion of Participant Work Shifts (not necessarily consecutive) during the Study Period

Number of Work Shifts	Number of Participants	Percentage of Total Participants
5	7	2.4%
6	15	5.2%
7	9	3.1%
8	17	5.9%
9	41	14.3%
10	51	17.8%
11	85	29.7%
12	41	14.3%
13	17	5.9%
14	3	1.0%
Total	286	100.0%

Participants were separated into two major categories based on completeness of their data: those who provided data from 5-8 work shifts (*n* = 48) and those providing data from 9 or more work shifts (*n* = 238). Across all facility types, over 83% of participants provided data from 9 or more shifts during the study period. The breakdown of complete data work shifts by facility type is shown in Table 3-6. In our sample controllers from En Route Centers were significantly more likely to provide complete data from 9 or more shifts during the study period than those from TRACONs or Towers (93% vs. 74.1% and 75.0%, respectively), (Pearson's Chi-Square (1, n = 286) = 17.859, $p < 0.001$).

Table 3-6. Number and Proportion of Participants Providing Complete Data from 5–8 Work Shifts and 9+ Work Shifts from each Facility Type

Facility Type	Number of Shifts	n	% of Total Participants
En Route	5-8 Work Shifts	9	6.8%
	9+ Work Shifts	124	93.2%
	Total	133	100.0%
TRACON	5-8 Work Shifts	21	25.9%
	9+ Work Shifts	60	74.1%
	Total	81	100.0%
Tower	5-8 Work Shifts	18	25.0%
	9+ Work Shifts	54	75.0%
	Total	72	100.0%
Total	5-8 Work Shifts	48	16.8%
	9+ Work Shifts	238	83.2%
	Total	286	100.0%

3.3.1.2 PVT Data

Participants were instructed to self-administer the PVT three times each work shift, yielding approximately 30 PVT scores per participant in a nominal 14-day period. PVT data was examined for completeness only for those participants whose activity logs were available and contained at least 5 work days. The distribution of missing PVT data is shown in Figure 3-7.

On average, 9% of PVT data were missing per participant. The missing data were not distributed evenly across the 3 PVT trials in each work shift: PVT data were most complete on the first trial (taken within the first 30 min of the work shift) (missing data $M = 7.57\%$) compared to the second and third trials (missing data *M*'s = 11.42% and 10.69%, respectively), $F(2, 504) = 14.978$, $p < 0.001$. A cutoff point of 25% missing PVT data was set for eliminating participants from further PVT-related analyses. This cutoff point was equivalent to two standard deviations from the mean. Its use resulted in the elimination of 16 participants. The breakdown of the eliminations by facility type is displayed in Table 3-7.

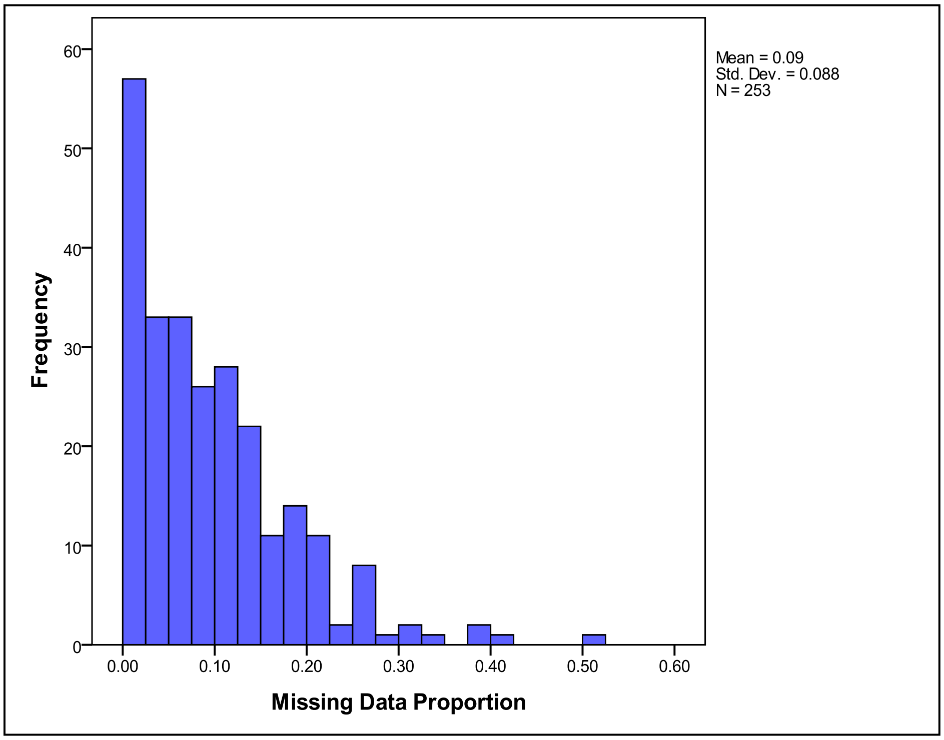

Figure 3-7. Proportion of missing PVT data for each participant across all trials.

Table 3-7. Number and Proportion of Eliminated Participants from each Facility Type

Facility Type	Number of Shifts		n	% of Participants
En Route	5-8 Work Shifts	Eliminated	1	16.7%
		Included	5	83.3%
		Total	6	100.0%
	9+ Work Shifts	Eliminated	3	2.5%
		Included	115	97.5%
		Total	118	100.0%
TRACON	5-8 Work Shifts	Eliminated	1	6.3%
		Included	15	93.8%
		Total	16	100.0%
	9+ Work Shifts	Eliminated	6	11.1%
		Included	48	88.9%
		Total	54	100.0%
Tower	5-8 Work Shifts	Eliminated	0	0
		Included	6	100.0%
		Total	6	100.0%
	9+ Work Shifts	Eliminated	5	9.4%
		Included	48	90.6%
		Total	53	100.0%

3.3.1.3 Actigraphy Data

Inspection of the actigraphy data revealed that data for 17 participants were at least partly unavailable because the actiwatches either stopped recording or otherwise malfunctioned. In those cases, sleep data (time to sleep, time awake) from the sleep/activity logs were used to supplement the actiwatch data. Participants' data were retained for analysis providing the majority of the data were available from the actiwatch or their logs. Determining completeness of the sleep data was complicated by difficulty distinguishing between a legitimate missing datum (i.e., the participant slept, but the actiwatch did not detect it) from an anomalous but not necessarily missing datum (i.e., the participant did not sleep at all during a time-off period, which the actiwatch recorded correctly). Note that actiwatch data were the primary source of sleep data; only when a participant's actiwatch malfunctioned or the data were missing for some undetermined reason were self-reported sleep log information utilized.

3.3.2 Controller Work Schedules

3.3.2.1 Five-Day Work Schedules

Three primary categories of 5-day schedules emerged:

- RRM: Counter-clockwise rapidly rotating with midnight shifts, including 2-2-1
- RR: Counter-clockwise rapidly rotating without midnight shits, including 2-1-2, 2-3, and 3-2
- Straight-5: Slowly rotating weekly schedules (e.g., 5 afternoon shifts followed by 5 day shifts, 5 early morning shifts, and 5 midnight shifts)

The remainder of the schedules fell into two other categories:

- Interrupted: The 5-day schedule met the characteristics of RRM or RR, but included a day off some time during the week
- Unclassified: The 5-day schedule did not meet the definitions of any of the above schedule types

None of the participants in the field study worked straight shifts (i.e., worked the same shift every week), and only one worked a forward rotating schedule (i.e., each succeeding shift during a week began at a later hour than the previous one.

The number of 5-day work weeks meeting each of the schedule criteria from each facility type is shown in Table 3-8, breaking down the RR and unclassified schedules into those that include midnight shifts and those that do not. Across all facilities, the dominant schedule was the counter-clockwise rapidly rotating with midnights (RRM), which accounted for 61.4% of the 272 5-day schedules. Within the RRM schedules, two patterns dominated: the 2-2-1 (AAEEM) and a variant that provided longer time off prior to the first early morning shift: ABEEM. These two schedules accounted for 37% and 35% of the total RRM schedules. Other variants included multiple midnight shifts, such as ABEMM. Note that the units in these distributions are work weeks, not participants, because an individual controller could contribute one, two or no complete work weeks during the study period.

Table 3-8. Number (and Percentage) of 5-day Schedule Types worked by Controllers from each Facility Type								
	En Route		TRACON		Tower		All Facilities	
Schedule Category	n	%	n	%	n	%	n	%
RRM	98	69.0%	35	62.5%	34	45.9%	167	61.4%
RR	11	7.7%	8	14.3%	12	16.2%	31	11.4%
Straight 5	2	1.4%	1	1.8%	2	2.7%	5	1.8%
Interrupted	24	16.9%	5	8.9%	19	25.7%	48	17.6%
Unclassified - Mid	5	3.5%	5	8.9%	5	6.8%	15	5.5%
Unclassified - No Mid	2	4.4%	2	3.6%	2	2.7%	6	2.2%
Total	142	100%	56	100%	74	100%	272	100%

Counter-clockwise rapidly rotating schedules with no midnight shifts (RR) accounted for 11% of the 5-day schedules, a low level not unexpected, given that participants working at least one midnight shift were solicited for the study. Ninety percent of the RR schedules were characterized as 2-x-2, that is, all began with two afternoon shifts and ended with two early morning shifts, with a variable non-midnight third shift. At most, these schedules had one quick turn, for example, prior to day three in AAEEE. Somewhat unexpected was the relatively large number of interrupted weeks, whch accounted for 17.6% of the 5-day weeks. Straight-5 slowly rotating schedules were rare in this sample (1.8% of the schedules).

This classification of schedule types permits aggregation into larger categories of those that are analyzable versus those that are not. Analyzable schedules inlcuded the two types of RRM schedules, those with and those without mids, plus the Straight-5s, for a total of 203 weeks. Those schedules considered unanalyzable were the interrupted and unclassifiable schedules, which totaled 69. Thus, 74.6% of the five day schedules were analyzable.

A comparison of schedules across facility types shows that the schedule types are not evenly distributed in the field study sample. RRM schedules are more prevalent in the Centers (69%) and the TRACONS (62.5%) than in the Towers (45.9%). In contrast, RR schedules are somewhat more prevalent in Towers (16.2%) and TRACONs (14.3%) than in Centers (7.7%). The greatest frequency of interrupted weekly schedules occured in Towers (25.7%), which seems to account for their higher level of unanalyzable schedules (35.1%) relative to either TRACONs (21.4%) or Centers (21.8%).

3.3.2.2 Six-Day Work Schedules

In addition to the 272 5-day schedules characterized above, there also were 75 6-day weeks with complete data (i.e., PVT, actigraphy and sleep logs). These 6-day schedules were classified using the same categories as for the 5-day schedules shown above in Table 3-8. However, one additional category was needed. Some weekly schedules that appeared unclassifiable actually fit a pattern: a nominal 5-day schedule, either RRM or RR, with the addition of an extra work shift (scheduled overtime) either at the beginning or at the end of the work week. For example, an AAEEM schedule might be extended to yield AAEEM(M) or (E)AAEEM. Similarly, an AABEE schedule might be extended to AABEE(B) or to (B)AABEE. Examination of prior and partial weeks from the FAA's BO data confirmed that these were normal 5-day schedules plus one day. Thus, they were distinguished from the unclassified category which fit no pattern. This 5-day plus OT category yielded 21 normal-plus overtime (OT) weeks out of the 75 6-day weeks, leaving only six unclassified weeks. If the OT day fell at the end of the week(OT-Final), the first five days were candidates for inclusion in our analysis of 5-day schedules. This procedure yielded 11 additional weeks, 9 in the RRM category and 2 in the RR category. The distribution of 6-day work week schedules is shown in Table 3-9.

Six-day schedules were higher in TRACONs at 38% of all TRACON schedules, compared to 12% for Towers and 17% for En Route Centers. Six-day weeks were interrupted at the same rate as 5-day weeks (17.3% and 17.6%, respectively). Defining a 6-day week as interrupted was a less certain undertaking than for a 5-day, which always had two (or more) days off between work weeks. Six-day weeks were considered interrupted if a single day off broke up a sequence that was recognizable as a normal schedule pattern. For example, AA-off-EEM-off would have been considered possibly an interrupted AAAEEM or an AAEEEM schedule. Certainty was not essential because these interrupted weeks were not analyzed due to their fragmentary nature.

Table 3-9. Number (and Percentage) of 6-day Schedule Types worked by Controllers from each Facility Type

Schedule Category	En Route		TRACONs		Tower		All Facilities	
	n	%	n	%	n	%	n	%
RRM	13	43.3%	13	37.1%	3	30.0%	29	38.7%
RR	0	0.0%	4	11.4%	1	10.0%	5	6.7%
Straight 6	0	0.0%	1	2.9%	0	0.0%	1	1.3%
OT Final – Mid	7	23.3%	2	5.7%	0	0.0%	9	12.0%
OT Final – No Mid	0	0.0%	2	5.7%	0	0.0%	2	2.7%
OT First – Mid	4	13.3%	4	11.4%	2	20.0%	10	13.3%
Interrupted	4	13.3%	6	17.1%	3	30.0%	13	17.3%
Unclassified – Mid	1	3.3%	2	5.7%	1	10.0%	4	5.3%
Unclassified - No Mid	1	3.3%	1	2.9%	0	0.0%	2	2.7%
Total	30	100%	35	100%	10	100%	75	100%

Repeating the pattern from the 5-day schedules, Centers and TRACONs yielded higher proportions of analyzable 6-day schedules than Towers (66.7% and 62.9% versus 40.0%, respectively).

3.3.3 Impact of Work Schedules on Amount, Timing and Efficiency of Sleep

3.3.3.1 Sleep Duration based on Actigraphy

Three sleep measures were obtained from the wrist activity monitors, which were worn 24 hours per day: sleep duration, timing and efficiency of sleep. Sleep duration was measured as total sleep time (TST) during each main sleep period plus any naps up to two hours that occurred between shifts during a work week. Sleep efficiency was derived from the sleep measures for the same sleep periods. It was defined as the ratio of actual sleep time to time in bed (TIB), i.e., the proportion of sleep in the TIB episode during which the participant actually slept. The actigraph software automatically generates sleep efficiency scores for each sleep episode. Sleep timing referred to the time at which participants went to sleep (time asleep) and time at which they awoke (time awake).

3.3.3.2 Sleep Duration as a Function of Shift Start Time

It was first examined whether the total amount of sleep controllers obtained varied depending on the shift type they planned to work following each sleep period, regardless of how that shift fit into a weekly schedule. Each work shift was categorized by the time at which the shift began, using the five shift categories developed by Della Rocco and colleagues (Della Rocco, et al., 2000): afternoon, mid-day, day, early morning and midnight. It was found that the amount of sleep obtained prior to a midnight shift was significantly less (M = 3.25 hrs) than the overall average sleep duration, p_1 = -228.264, $z(25)$ = -14.404, $p < 0.001$. In addition, significantly less sleep (M = 5.39) was obtained by participants before an early morning shift, p_2 = -85.075, $z(25)$ = -5.606, $p < 0.001$, whereas the most sleep was obtained before either a mid-day (*M* = 6.76 hrs) or an afternoon (*M* = 6.94 hrs) shift; these latter two shifts were not significantly different from the average sleep duration. Day shifts (those beginning between 08:00 and 09:59) were infrequent and did not differ from the average sleep duration. These sleep patterns replicate prior CAMI findings (Cruz & Della Rocco, 1995). Mean total sleep times for each of these shift start times are shown in Table 3-10.

Table 3-10. Duration of Sleep in Hours Before Various Shift Start Times

Shift Start Times	Mean Hours Slept	Standard Deviation	n
Early shift (starts before 08:00)	5.39	1.39	369
Day shift (starts between 08:00 and 09:59)	6.41	1.21	14
Mid-day shift (starts between 10:00 and 12:59)	6.76	2.01	111
Afternoon shift (starts between 13:00 and 19:59)	6.94	1.51	327
Midnight shift (starts between 20:00 and 01:00)	3.25	2.13	140

3.3.3.3 Time Asleep as a Function of Shift Start Time

The majority of controllers tended to go to sleep late in the evening (*M* = 690.22[12] or 11:30 pm, except for those working a midnight shift). Given the variance around this time, the time asleep data was transformed so that 12:00 p.m. received the value of 0.00 to allow for a continuous measurement from noon to midnight through early morning and ending at noon, as shown in Figure 3-8

[12] For ease of computation, time asleep and time awake were computed in minutes, and then transformed back to clock time.

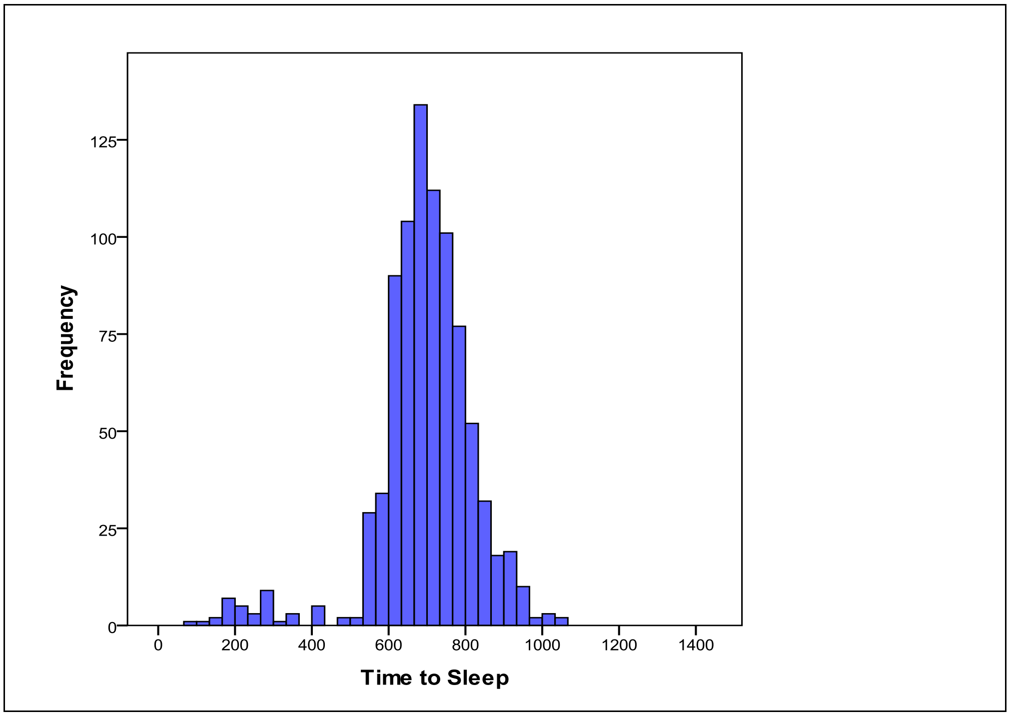

Figure 3-8. Frequency distribution of time asleep, across A, B, D, and E schedules, where 0 = 12:00 (noon), 720 = 24:00 (midnight), and 1440 = 11:59.

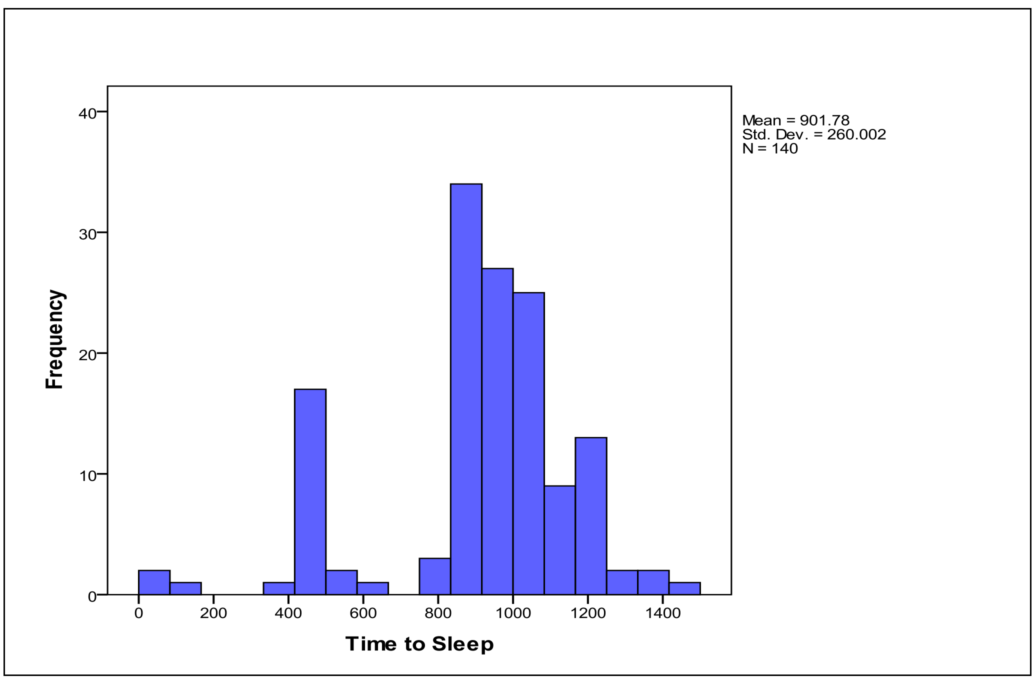

Figure 3-9. Frequency distribution of time asleep prior to midnight shifts. Note that in contrast to Figure 3-8, the origin on the x-axis is 00:00 (midnight), so the midpoint of the scale (720 min) is noon (12:00). Mean and modal times asleep are both 15:03 (or 3:03 p.m.). A morning sleep period began around 08:00, suggesting that participants were transitioning from a prior midnight shift rather than an early morning shift.

Previous CAMI research found that although the time at which controllers awoke varied depending on when their next shift started, time at which they went to sleep did not vary according the upcoming shift start time (Cruz & Della Rocco, 1995). However, this was not the case in the present study. As can be seen in Table 3-11, controllers who had an upcoming early shift (beginning prior to 08:00) went to sleep significantly earlier (*M* = 638.73 or 22:38) on average than those who faced a mid-day (*M* = 752.89 or 00:33) or an afternoon shift (*M* = 734.16 or 00:14), p_1 = 114.123, $z(25)$ = 9.089, $p < 0.001$, and p_2 = 95.436, $z(25)$ = 9.737, $p < 0.001$, respectively. In addition, controllers who had an upcoming day shift (beginning from 08:00 to 09:59) tended to go to sleep later (*M* = 675.84 or 11:16 pm) than those with an early shift, although the time difference was only marginally significant, p_3 = -77.047, $z(25)$ = 1.815, p = 0.081. Those controllers who had an upcoming midnight shift were not included in this comparison in order to reduce the variance while examining comparisons between the other shift start times. Participants anticipating a midnight shift went to sleep much earlier than those with any other shifts, around 15:00 (15:03, as shown in Figure 3-8), because their time to sleep was constrained by the midnight shift start time.

Table 3-11. Time Asleep and Time Awake as a function of Upcoming Shift Start Times

	Shift Start Time					
	Early (01:00–07:59)	Day (08:00–09:59)	Mid-Day (10:00–12:59)	Afternoon (13:00–19:59)	Midnight (20:00–00:59)	Weekly Mean
Time Asleep	22:38	23:16	00:33	00:14	15:03	23:30
Time Awake	04:20	06:20	07:16	07:29	18:03	07:42

3.3.3.4 Time Awake as a Function of Shift Start Time

The majority of controllers woke up before 08:00 before all shifts except midnight shifts (*M* = 462.15 min or 07:42, *SD* = 288.27), as shown in Table 3-11. However, those who had an upcoming early morning shift (*M* = 259.77 min or 04:20) or a day shift (*M* = 380.36 min or 06:20) tended to wake up significantly earlier in clock time than average, p_2 = -192.284, $z(25)$ = -15.952, $p < 0.001$, and p_3 = -70.397, $z(25)$ = -3.253, p = 0.004. Participants who had an upcoming mid-day or afternoon (i.e., B or A [see Figure 3-6]) shift did not wake up significantly earlier or later than the average of 07:42. Those who were preparing for a midnight shift woke up significantly later (*M* = 1083.21min or 18:03) than the average following their afternoon nap, p_1 = 637.920, $z(25)$ = 24.317, $p < 0.001$.

Unlike participants in the Cruz and Della Rocco (1995) study, controllers in the present study adjusted both their time asleep and time awake as a function of the upcoming shift start time.

3.3.3.5 Sleep Duration as a Function of Schedule Type

The prior analyses examined sleep patterns as a function of individual shift start times, but did not consider their place in a weekly schedule. The next set of analyses compared weekly work schedules with and without midnight shifts to see how these schedules influenced total sleep across a week and before specific shift types. These schedules were selected in order to compare findings in the present study with those obtained in field studies conducted over a decade ago (see Della Rocco and Nesthus, 2005). Two weekly schedules were compared: one RRM schedule type, the 2-2-1 (two afternoons, two early mornings and one midnight shift, or AAEEM) and one RR schedule called the 2-x-2. The latter category included the 2-1-2 studied in several prior CAMI studies (including Cruz & Della Rocco, 1995) and involves two afternoons, one mid-day, and two early morning shifts (AABEE). However, due to the limited number of current participants working the 2-1-2 schedule (*n* = 10) for whom complete data were available (i.e., log, PVT and actigraph data), this category was expanded to include other schedules that began with two afternoon shifts and ended with two early morning shifts, but that differed in the mid-week shift: AADEE, AAAEE, and AAEEE. Weekly schedules that did not fall into either the 2-2-1 or 2-x-2 categories were not included in the schedule-type analyses. A total of 83 participants were included, 52 working the 2-2-1 schedule and 36 working the 2-x-2. Five of these participants worked both 2-2-1 and 2-x-2 schedules during the study period. Including those five participants was not problematic because partitioning of individual variability at the day/trial level was performed inherently in the multilevel analyses.

Both schedule type and day progression (Day 1 through Day 5) were used first as predictors of mean total sleep time over the entire week. When the schedule type (2-2-1 versus 2-x-2) was entered by itself into the model, the effect was significant, $p_1 = 37.95$, $z(21) = 2.823$, $p = 0.011$. This suggests that participants slept significantly longer over the week when they had no midnight shift in their schedule (2-x-2) than when their schedule included a midnight shift (2-2-1). When the day progression component within the weekly schedule was included, both effects were significant, $p_1 = 35.153$, $z(21) = 2.589$, $p = 0.017$ for schedule type, and $p_2 = -50.774$, $z(20) = -10.503$, $p < 0.001$ for day progression. The mean amount of sleep obtained on each night of the week for each schedule type is shown in Table 3-12. These results indicate that (a) participants obtained significantly less sleep when they worked the 2-2-1 schedule than the 2-x-2 schedule; and (b) both groups slept progressively less over their work week, confirming earlier CAMI findings (Cruz, et al., 1995).

The differences between the schedule groups are evident on days 3 and 5. These are days when the 2-2-1 group experienced a quick turn, typically of 8 to 9 hours, prior to those shifts. The 2-x-2 group had the possibility of one quick turn prior to Day 3 (if they worked the AAEEE schedule), but otherwise this turn was longer, permitting one hour more sleep before the shift on Day 3 than the 2-2-1 group obtained. The 2-x-2 group obtained three hours more sleep before Day 5 prior to an early shift, when the 2-2-1 group only slept for 2.5 hours during the day between the Day 4 early morning shift and the subsequent Day 5 midnight shift, which began sometime between 21:00 and 24:00 on the same day.

Table 3-12. Mean Sleep Duration in Minutes (Standard Deviation in parentheses) and Hours over Days for the 2-2-1 and 2-x-2 Schedules

Schedule	Day 1	Day 2	Day 3	Day 4	Day 5
2-2-1	***A*** 425.33 min (115.58) 7.1 hr	***A*** 405.91 min (98.84) 6.8 hr	***E*** 314.39 min (79.17) 5.2 hr	***E*** 329.30 min (85.76) 5.5 hr	***M*** 152.42 min (91.28) 2.5 hr
2-x-2	***A*** 437.78 min (75.31) 7.3 hr	***A*** 405.80 min (110.08) 6.8 hr	***A/B/D/E*** 373.09 min (106.29) 6.2 hr	***E*** 323.38 min (67.43) 5.4 hr	***E*** 329.29 min (78.06) 5.5 hr

Notes: 1. Statistical analyses used minutes rather than hours of sleep, but hours are presented for ease of understanding. 2. Shifts for each day are indicated by letter in cell: A, B, D, E, and M.

3.3.3.6 Time Asleep as a Function of Schedule Type

When entered by itself, schedule type (2-2-1 versus 2-x-2) did not affect the time at which participants went to sleep, $p_1 = 20.92$, $z(21) = 0.273$, $p = 0.787$, nor did the schedule type have an effect when the day progression was introduced as well, $p_1 = 32.261$, $z(21) = 0.462$, $p = 0.648$. However, day progression itself was significant, $p_2 = 127.693$, $z(21) = 5.763$, $p < 0.001$, indicating that participants went to sleep earlier as the work week progressed, regardless of whether they were working a 2-2-1 or a 2-x-2 schedule.

3.3.3.7 Time Awake as a Function of Schedule Type

The schedule type entered alone influenced the time at which participants awoke, $p_1 = -103.613$, $z(21) = -3.489$, $p = 0.003$. Participants who worked the 2-x-2 schedule that included no midnight shifts tended to wake up significantly earlier before a shift on average than those who worked the 2-2-1 schedule that included a midnight shift. With the day progression effect included, this effect remained significant, $p_1 = -103.915$, $z(21) = -3.591$, $p = 0.002$. The day progression effect suggests that over the course of the week, participants tended to awaken later, p_2 = 37.784, $z(21)$ = 3.699, p = 0.002. However, when the day effect was restricted to Days 1–4 (which excluded sleep prior to the midnight shift on Day 5 in the 2-2-1 schedule), the results reversed, p_1 = 47.837, $z(21)$ = 2.782, p = 0.008, and p_2 = -79.976, $z(21)$ = -13.364, $p < 0.001$. These results indicate that up to Day 4, controllers who worked the 2-2-1 schedule woke up significantly earlier in clock time than those who worked the 2-x-2 schedule; on Day 5 this pattern reverses, when participants working the midnight shift typically take a nap during the day and awaken sometime in the afternoon in preparation for the midnight shift. This Day 1–4 pattern is expected, as the first four shifts in a 2-2-1 schedule involve two afternoon shifts followed by two early morning shifts. The first two days of the 2-x-2 schedule also are afternoon shifts, but these are typically followed by either a mid-day shift, a day shift or another afternoon shift, allowing a later wake-up time than the early morning shift in the 2-2-1 schedule. In addition, all controllers generally appeared to awaken progressively earlier up to Day 4, regardless of schedule type, another pattern predicted on the basis of the progression of shift types over days.

3.3.3.8 Efficiency of Sleep from Actigraph Data

The efficiency of sleep on average was 82.84, with a fair amount of variability for a percentage measure (*SD* = 10.12). Scores in this study ranged from 0.83 to 100, as shown in Figure 3-13. The norm for sleep efficiency is considered to be 85 to 100, so the average in this study was somewhat below the norm. The mean efficiency of sleep only differed significantly from average for the sleep period prior to a midnight shift, p_1 = -4.806, $z(25)$ = -3.400, p = 0.001, when it was significantly lower than average, with a mean of 79.15. This finding is in keeping with earlier CAMI results showing that sleep efficiency is commensurate with the duration of sleep (Nesthus, Cruz, Boquet, Dobbins & Holcomb, 2003); participants slept the least prior to midnight shifts. The lower sleep efficiency during afternoon naps prior to midnight shifts suggests that controllers had difficulty falling asleep during the day, when circadian pressures encouraged them to be awake.

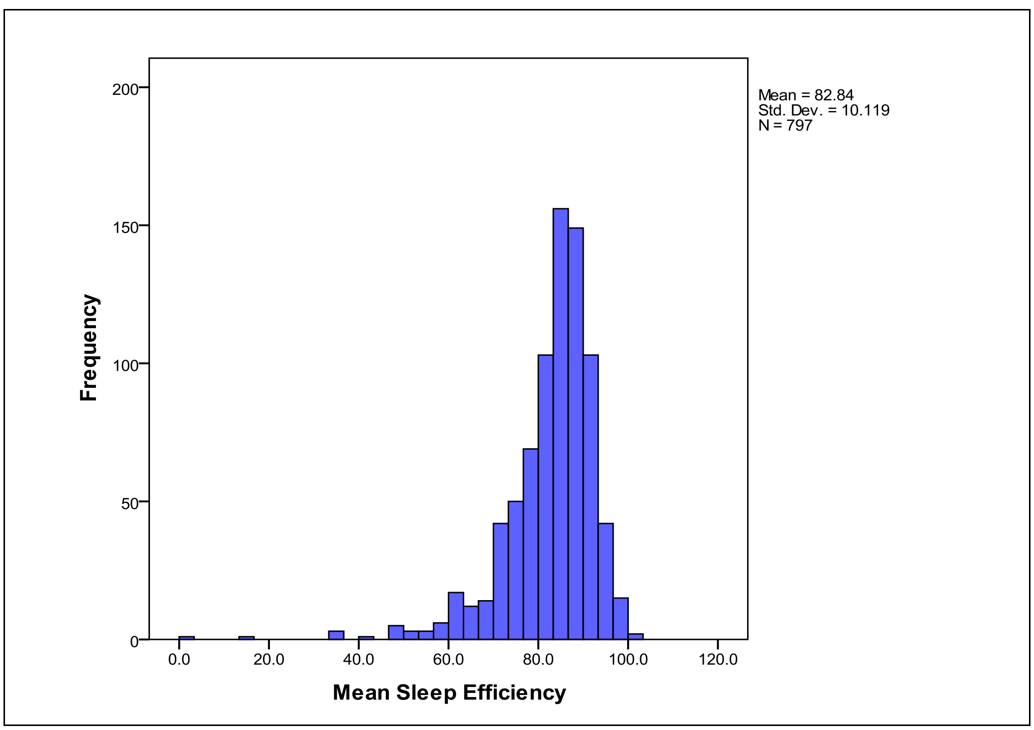

Figure 3-10. Frequency distribution of average sleep efficiency scores across participants.

The efficiency of sleep was not affected by the schedule type (i.e., 2-2-1 vs. 2-x-2) when schedule type was entered alone, p_1 = 0.636, $z(21)$ = 0.321, p = 0.752. It remained non-significant even when the day progression effect was entered, p_1 = -1.803, $z(21)$ = -0.972, p = 0.343. There was no effect of day progression on participants' sleep efficiency on average, p_2 = -1.447, $z(21)$ = -1.156, p = 0.261, despite the significant effect of shift start times and significantly lower sleep efficiency prior to midnight shifts compared to other shift start times, when weekly schedule was not taken into account. This lack of significance may reflect the smaller *n* in the schedule comparison relative to the prior findings, which were based on the entire sample.

3.3.4 Impact of Work Schedules on Controller Alertness Measured by PVT Performance

Two primary measures of PVT were used in determining participant cognitive alertness and fatigue: lapses (responses slower than 500 ms) and response speed (reciprocal of reaction time in ms). Rather than using response speed in the analyses, deviation scores from each individual's baseline were used because response speed is known to vary greatly among individuals, which may obscure differences associated with variables of interest. The mean of the top 10% of each individual's performance scores served as a baseline proxy, as it was not possible to obtain baseline performance measures when the participant was known to be fully rested (all PVT measures were taken at work and began on various days of the work week).

For both measures (lapses and response speed), the sample size of 211 was used, due to elimination of participants with more than 25% of missing PVT data (*n* = 16). Additionally, only participants with 9 or more work shifts were included in the initial analysis by shift type. Subsequent analyses of schedule type included participants with 5-8 work shifts.

Because earlier CAMI shiftwork studies had found significant effects of controller age on alertness and vulnerability to schedule factors (e.g., Nesthus, et al., 2003, 2005), participant age and years of experience as controllers were included in the analyses of alertness, testing both their main effects and their role as moderators of relations between schedules and PVT performance.

3.3.4.1 Overall performance

First, lapses were aggregated across trials (within days) and work shifts for each participant to determine the average frequency of lapses and their variability among individuals.

The mean number of lapses presented a positively skewed distribution (as shown in Figure 3-14): the majority of participants had very few lapses on average, with a grand mean of 1.9 lapses on each 5-minute trial.

Standard deviations of these lapses were also examined, partly as a way to characterize the lapses (i.e., descriptive statistics) and partly to justify the appropriateness of multilevel modeling. Multilevel modeling can be used whenever individual differences can be detected in the variables of interest. The distribution of the standard deviation for lapses (Figure 3-12) indicates that the variability was just as wide as the mean. This means that although participants committed few lapses in general, many controllers performed significantly worse at some time during the study period, supporting our decision to use multilevel modeling. The distribution also suggests that lapses on the 5-min PVT task are sufficiently variable to detect fatigue, despite the test's shorter length than the established 10-min task (Basner & Dinges, 2011; Loh, Lamond, Dorrian, Roach & Dawson, 2004).

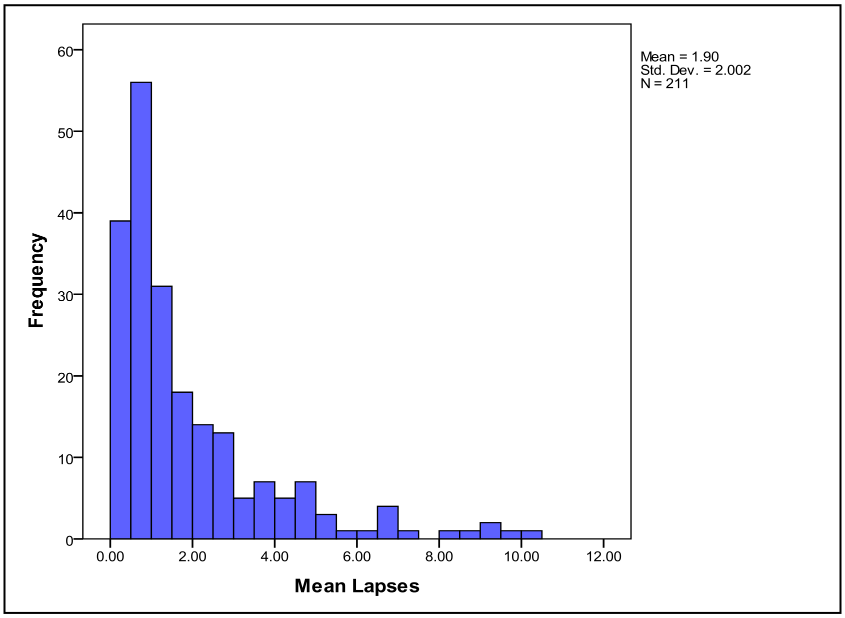

Figure 3-11. Frequency distribution of mean lapses across all participants.

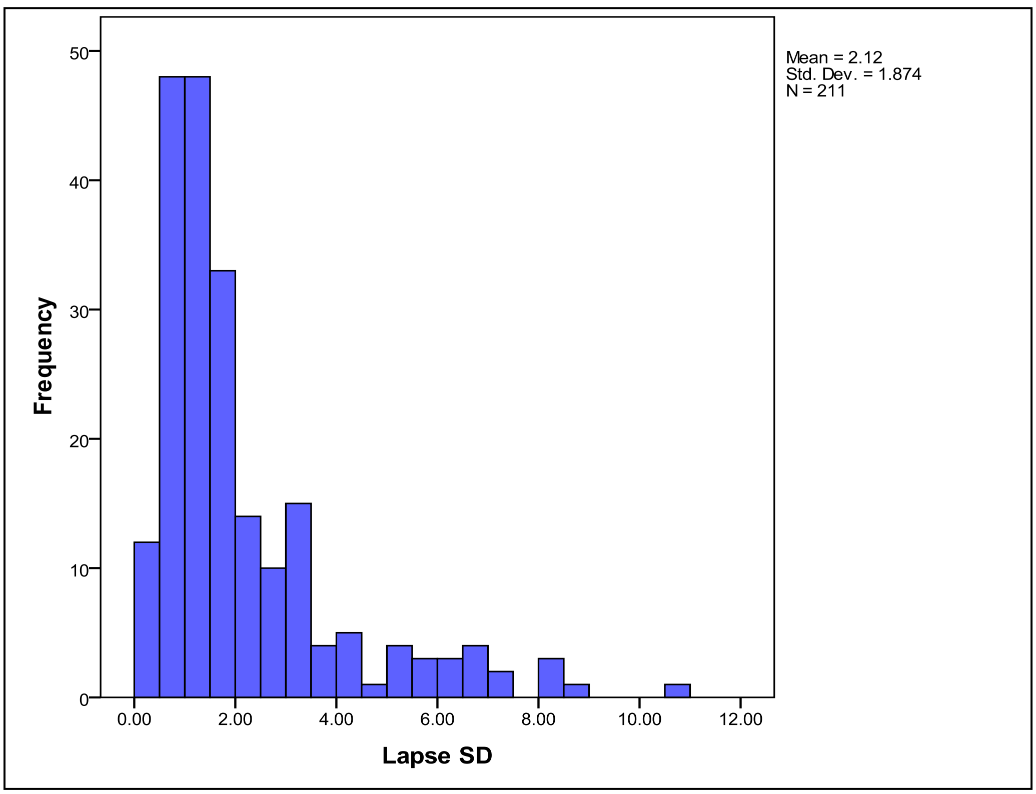

Figure 3-12. Frequency distribution of the standard deviations of lapses across all participants.

Response speeds (reciprocal of reaction time in ms) were converted to deviations from individual 'baselines' calculated as the mean of the 10% fastest scores for each participant. Therefore, the response speed scores are typically negative. They were then aggregated across trials (within days) and work days (Day 1 to Day 5) for each participant to determine the average response speed and its variability among individuals.

The mean of the mean response speed was -0.00065; the scores formed a negatively skewed distribution where the majority of response speeds are clustered near their top speeds (i.e., nominal response speed for each individual), as can be seen in Figure 3-13. However, the variability of the standard deviations of the response speeds as shown in Figure 3-14 was not as widely distributed as the mean response speeds, suggesting that the variability across individuals is not as large as the variability within individuals.

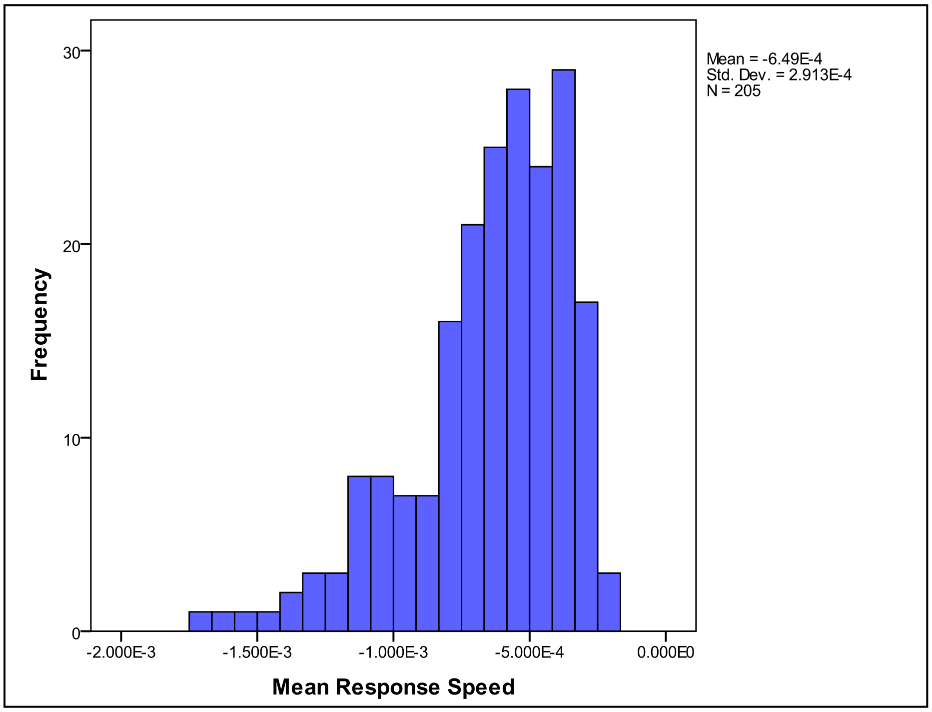

Figure 3-13. Frequency distribution of mean response speeds as deviation scores from the fastest 10% of trials across all participants.

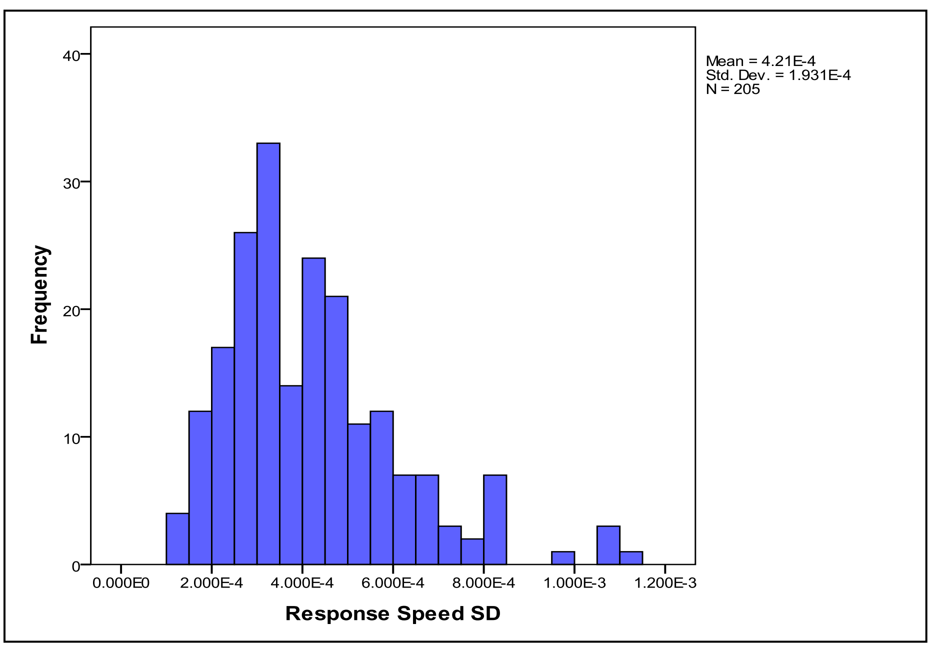

Figure 3-14. Frequency distribution of standard deviations of response speeds as deviation scores from the fastest 10% of trials across all participants.

3.3.4.2 PVT Performance by Shift Start Time

Alertness varied with shift start times, regardless of where the shift fell within a weekly schedule. Responses were slowest and lapses most frequent during midnight shifts compared to other shifts, p_1 =

-0.000385, $z(25) = -6.573$, $p < 0.001$, and $p_1 = 1.887$, $z(25)$ 4.639, $p < 0.001$, respectively. Additionally, participants tended to respond more slowly on early morning shifts, $p_2 = -0.000116$, $z(25) = -2.928$, $p = 0.008$; however, lapses did not differ from those in later shifts, $p_2 = 0.288$, $z(25) = 1.176$, $p = 0.251$. This could be due to a highly skewed distribution of the number of lapses, as described in Section 3.3.4.1.

3.3.4.3 PVT Performance: Beginning versus End of Shift

In order to determine whether individuals' alertness changed over the course of a work shift, lapses from the beginning of a shift (Trial 1) were compared to those from the end of the shift (Trial 3). Lapses increased significantly from the beginning to the end of a work shift, as shown in Table 3-13, $p_1 = 0.884$, $z(25) = 4.109$, $p < 0.001$. This held for all shift types and days of the work week.

Table 3-13. Mean Lapses and Standard Deviation at Beginning and End of Shifts

Trial	Mean Lapses	SD
Trial 1 (Beginning of shift)	1.84	4.54
Trial 3 (End of shift)	2.57	5.35

In addition, participants responses were significantly slower on average at the end of the shift compared to the beginning of the shift, $p_1 = -0.000162$, $z(25) = -5.853$, $p < 0.001$, as shown in Table 3-14. These declines in alertness across the shift were not moderated by participant age or years of experience. However, older and more experienced controllers performed the PVT task faster overall than younger or less experienced ones, $b_{01} = 0.000007$, $z(25) = 2.610$, $p = 0.015$, and $b_{01} = 0.000006$, $z(25) = 2.329$, $p = 0.028$, respectively. This result is inconsistent with previous CAMI findings that showed older controllers (over age 40) performing less well than younger ones on tasks involving speed and working memory (Nesthus, et al., 2003, 2005). The earlier CAMI findings are in keeping with a significant literature on age and speed of responding, which suggests that the older and more experienced controllers in the present study may have adopted a speed-accuracy trade-off strategy, though no effects of age or experience were found for lapses.

Table 3-14. Mean Response Speed (deviation from the baseline) and Standard Deviation at Beginning and End of Shifts

Trial	Mean Response Speed	SD
Trial 1 (Beginning of shift)	-0.000549	.000488
Trial 3 (End of shift)	-0.000694	.000539

3.3.4.4 PVT Performance Across Work Week

In order to determine whether fatigue accumulated across the work week, the day of week effect on PVT performance was examined. The number of PVT lapses was found to increase as the week progressed, $p_1 = 0.458$, $z(25) = 5.383$, $p < 0.001$, as shown in Table 3-15.

Table 3-15. Mean PVT Lapses and Standard Deviation on Days 1–5		
Day	Mean Lapses	SD
Day 1	1.95	4.81
Day 2	1.62	3.42
Day 3	2.15	4.73
Day 4	2.42	5.07
Day 5	3.13	6.57

Also, response speed slowed significantly across the work week, p_1 = -0.000092, $z(25)$ = -7.709, $p <$ 0.001, as shown in Table 3-16.

Table 3-16. Mean PVT Response Speed (deviation around the baseline) and Standard Deviation at Days 1–5		
Day	Mean Response Speed	SD
Day 1	-0.00055	0.00047
Day 2	-0.00051	0.00046
Day 3	-0.00064	0.00052
Day 4	-0.00070	0.00051
Day 5	-0.00079	0.00059

The day effect on both response speed and lapses was moderated by age and years of experience: Both age and experience appeared to protect against increasing fatigue as measured by response speed, b_{01} = 0.000003, $z(25)$ = 2.167, p = 0.040, and b_{01} = 0.000003, $z(25)$ = 1.955, p = 0.061, respectively. The moderating effects of age and years of experience were smaller for the day-lapse relationship, b_{01} = -0.0186, $z(25)$ = -1.935, p = 0.064, and b_{01} = -0.0188, $z(25)$ = -1.837, p = 0.078, respectively.

3.3.4.5 PVT Performance by Schedule Type

Two specific work schedules, the 2-2-1 (RRM) and the 2-x-2 (RR, previously described in 3.3.3.5), were compared to determine whether the presence of a midnight shift and two quick turns during a work week influenced controllers' behavioral alertness. It was found that schedule type alone did not impact participants' response speed, p_1 = -0.000002, $z(24)$ = -0.028, p = 0.979, or lapses, p_1 = -0.4148, $z(24)$ = -0.923, p = 0.366. However, the day progression was statistically significant for both response speed, p_2 = -0.000097, $z(24)$ = -6.447, p < 0.001, and lapses, p_2 = 0.486, $z(24)$ = 4.302, p < 0.001, when entered along with the schedule variable, replicating the day effect reported in section 3.3.3.5. This day effect reflects cumulative fatigue across the work week.

The decline in measured alertness across the work week parallels the finding that controllers obtained less sleep per day as the work week progressed (reported in section 3.3.3.5). The end of the week involves a midnight shift for those working the 2-2-1 schedule and back-to-back early morning shifts for those working the 2-x-2 schedule. The amount of sleep prior to these shifts was found to be significantly less than before other shifts (as reported in section 3.3.3.1), which is likely to have affected controllers' alertness as measured by the PVT, along with circadian factors. To test this hypothesis, the relationship between total sleep duration (TSD) and PVT measures was examined. TSD significantly predicted lapses, p_1 = -0.00785, $z(19)$ = -4.112, p = 0.001 (r = -.752), indicating that the shorter the sleep duration prior to a shift, the more lapses the controller experienced during the shift. Similarly, TSD significantly predicted response speed, $p_1 = 0.000002$, $z(19) = 6.698$, $p < 0.001$: the shorter the sleep duration prior to a shift, the slower the response speed during that shift.

3.3.4.6 PVT Performance by Time Off between Shifts

A critical question is whether the significant relationship between amount of sleep and alertness is driven by the duration of time off between shifts, because rest and recovery sleep are obtained during these off-duty periods. Two sets of analyses were conducted to: (a) determine the impacts of longer durations of time off ranging from 8 hours to 72 hours on alertness (PVT response speed and lapses); and (b) determine the impact of turns ranging from 8 to 12 hours on amount of sleep and resulting alertness.

3.3.4.6.1 Long Duration Time Off

Response speeds increased significantly when participants had greater time off between shifts, regardless of shift or schedule types, $p_1 = 0.000003$, $z(25) = 4.640$, $p < 0.001$. Similarly, lapses decreased significantly as the time between shifts increased, $p_1 = -0.0121$, $z(25) = -4.309$, $p < 0.001$. These findings indicate that alertness improves when time between shifts increases, presumably because the longer breaks afford sufficient time for controllers to recuperate. The relations between duration of time off between shifts and response speed can be seen in Figure 3-15; the relations between time off and lapses is shown in Figure 3-16.

In Figure 3-15, each line on the graph is a linear regression line representing a single participant's response speed predicted by hours between the previous and current shift. Performance is best (i.e., least deviated from the baseline of the mean 10% fastest response speeds) at the 0.000 point (top of ordinate). The slope of the line indicates the impact of time off between shifts, beginning with the shortest time off. A slope close to zero indicates a relatively small effect of time off, whereas a steeply sloped line indicates a significant impact. Variability in time-off effects is seen between individuals and in different facilities. In some facilities participant responses are relatively homogeneous and show the smallest impact of brief times off, whereas much more variability between participants and greater time-off effects are seen in other facilities. This variability may reflect differences in schedules worked at various facilities or other facility-specific features.

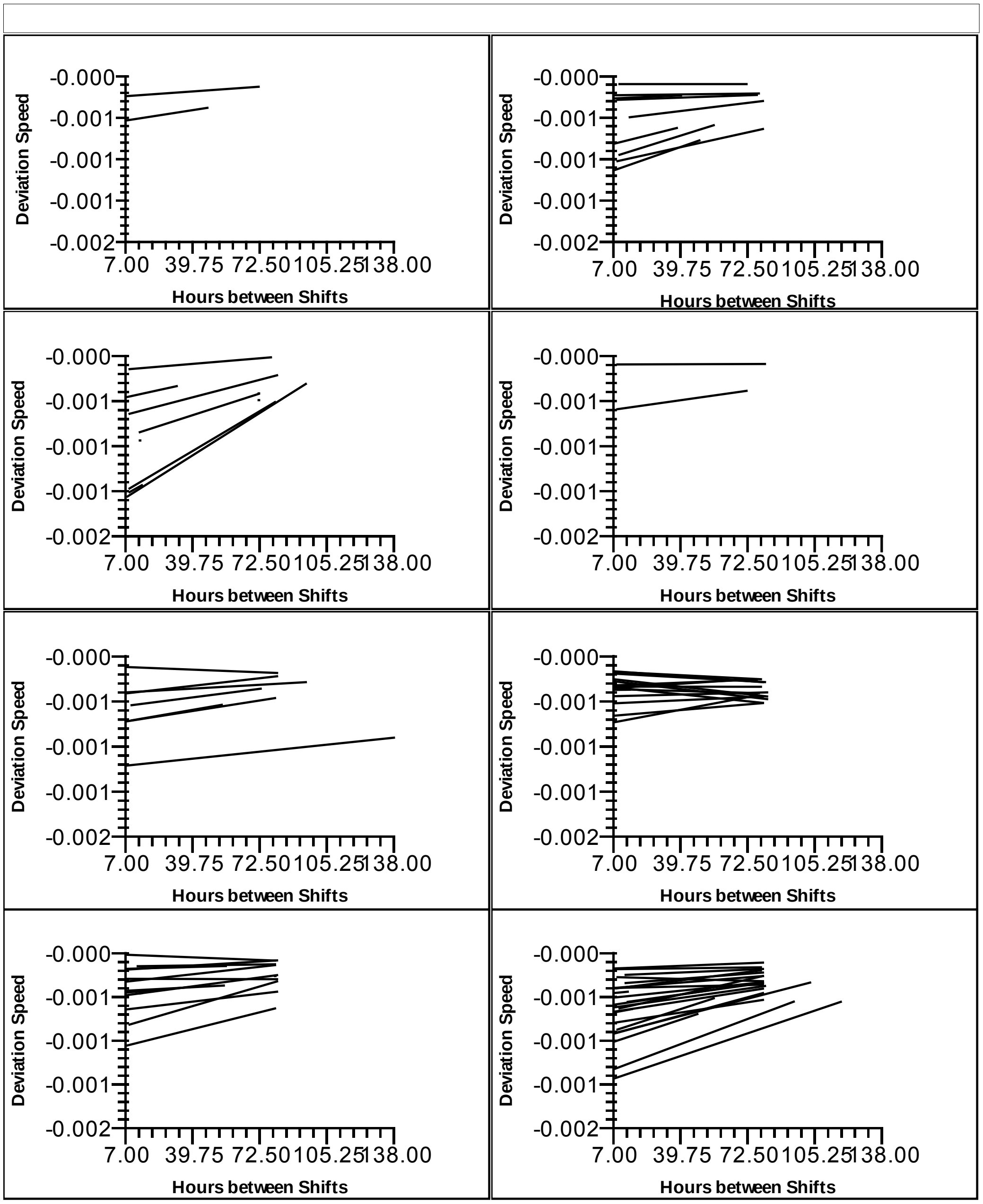

Figure 3-15. The model relationship between response speed (deviated around baseline) and time between shifts for individual respondents in illustrative facilities.

In Figure 3-16, the nominal baseline for lapses was 0. As in Figure 3-15, near-zero slopes signify little effect of duration of time off between shifts for individual controllers, whereas sharp slopes indicate a significant impact of time off duration, with a greater number of lapses seen at the shortest durations (8 hours). Negative slope reflects the benefits of recovery over longer durations of time off.

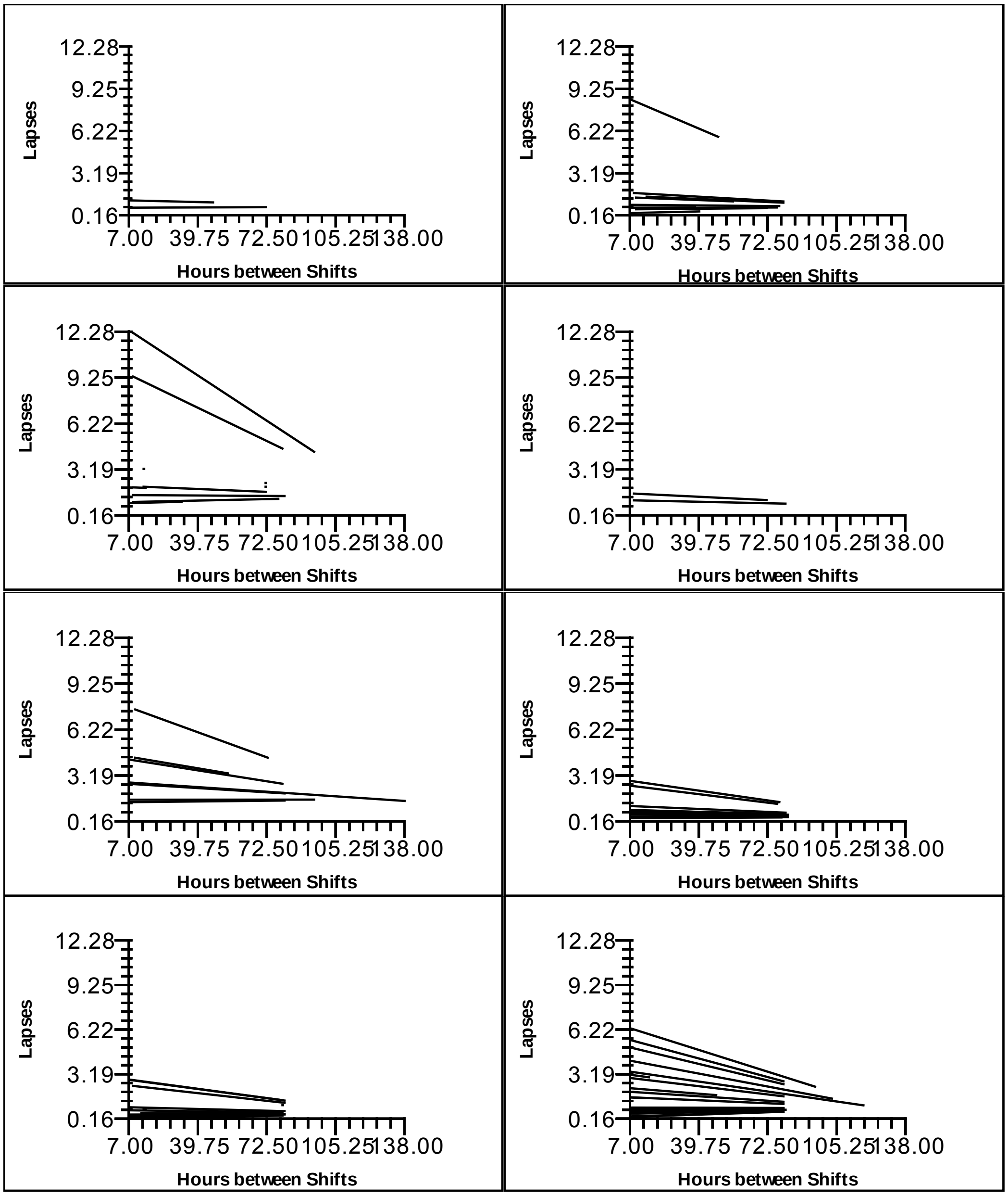

Figure 3-16. The model relationship between lapses and time between shifts for individual respondents in illustrative facilities (same participants and facilities as in Figure 3-15).

3.3.4.6.2 Turn Duration Effects on Controller Sleep and Alertness

A preliminary analysis of the impact of turns less than 12 hours was conducted using only a portion of the total data set associated with the schedule comparisons (2-2-1 vs. 2-x-2). Similar to prior CAMI research, this research considered time off between shifts ranging from 8 to 12 hours (Nesthus, Cruz, Boquet, Dobbins, and Holcomb, 2003). Because of their greater variability and potential for countermeasures, turns less than 12 hours prior to early morning shifts were the primary focus of this analysis. For comparability to Nesthus, et al. (2003), only the following work schedule categories were included in the analyses:

1) DAY 3 Early Morning Turns Less than 12 Hours: Time off between work shifts 2 and 3 must be equal to 12 hours or less
   a) xxEEE - time off between other shifts was longer than 12 hours (n = 18)
   b) xxEEM - time off between work shifts 4 and 5 must also be 12 hours or less; the other turns were longer than 12 hours (n = 112)

2) DAY 4 Early Morning Turns Less than 12 Hours: Time off between work shifts 3 and 4 must be equal to 12 hours or less
   a) xxxEE - time off between other shifts was longer than 12 hours (*n* = 25)
   b) xxxEM - the time off between work shifts 4 and 5 must also be 12 hours or less; the other turns were longer than 12 hours (*n* = 13)

In the above schedules, 'x' represents other shift types, that is, A, B, D or E. Thus, an xxEEE schedule might be AAEEE or ABEEE; likewise, an xxEEM might be AAEEM or ADEEM; xxxEE might be ABDEE; xxxEM could be AABEM[13].

The only times off between shifts that were included in the analyses were the following:

- Turns less than 12 hours prior to Day 3 early morning shift from category 1 above
    - Comparison of (a) xxEEE and (b) xxEEM examines the potential effect on Day 3 turns of anticipating a midnight shift on Day 5
- Turns less than 12 hours prior to Day 4 early morning shift from category 2 above
    - Comparison of (a) xxxEE and (b) xxxEM examines the potential effect on Day 4 turns of less than 12 hours of anticipating a midnight shift on Day 5
    - Comparison of Day 3 in category 1 vs. Day 4 in category 2 permits examination of day of week on which the turn to early morning shift occurs

Note that time off prior to shift 4 in category 1(a) was not a QT, but these data were included in the analysis for comparison of QT with longer durations of time off.

Turns were defined in two ways, continuous and categorical. First, as a continuous variable, turns for this assessment ranged from 7.25 to 12.25 hours.[14] As shown in Figure 3-17, almost 82% of the turns less than 12 hours prior to early shifts in the present sample were between 8 and 10 hours, with a mean of 9.5 hours.

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[13] Five of the 112 xxEEM schedules and one of the 25 xxxEE schedules were not counter-clockwise rotations (e.g., BAEEM, EBEEM or MABEE).

[14] According to FAA rules at the time of data collection, the minimum time off between shifts was 8 hours (FAA, 2010, sect 2-6-7, Basic Watch Schedule). While a few of the turns were less than 8 hours, these appear to represent controllers signing in early when coming on shift or late when going off shift, based on the FAA's Business Objects data.

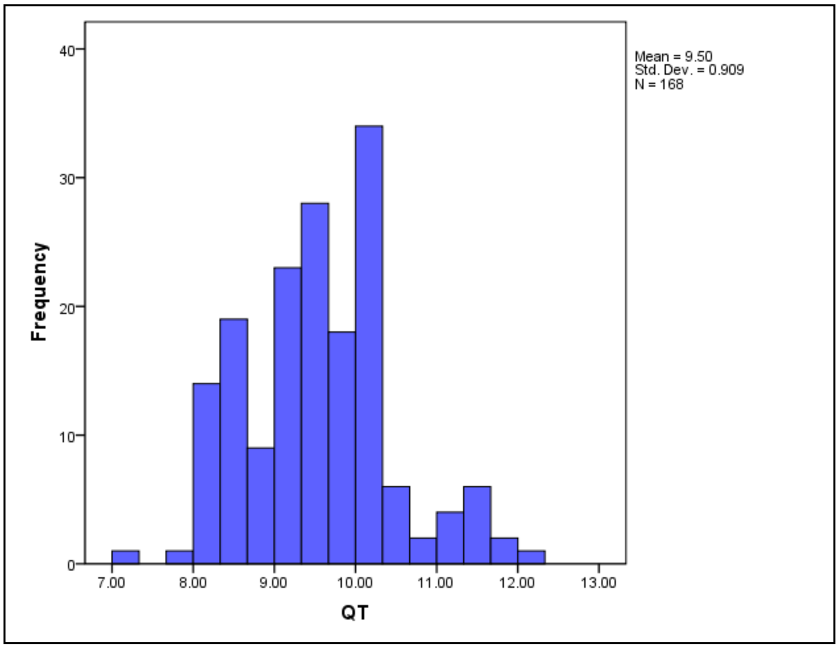

Figure 3-17. Frequency distribution of turns less than 12 hours in the analyzed work weeks.

Second, turns of less than 12 hours were divided into ordinal categories by rounding the continuous variables and then further aggregating some low frequency categories. The final categories depicted for each category of data are shown below in Tables 3-17 and 3-18. These categories were created in addition to the continuous variable because for turns of less than 12 hours the effect may not be linear in nature (e.g., changes in sleep or alertness may be detected between 9-hour turn versus 8-hour turn, but not between 10-hour turn versus 9-hour turn).

Table 3-17. Frequency and Percentage of Hours Off prior to Shift 3 (before the First Early Morning Shift) in Participant Work Week Categories 1(a) and 1(b)

Work Week Category	Hours off	Frequency	Percent
(a) xx**E**EE	7-8	2	11.1%
	9	8	44.4%
	10	8	44.4%
	11-12	0	0.0%
	Total	18	100.0%
(b) xx**E**EM	7-8	13	11.6%
	9	32	28.6%
	10	52	46.4%
	11-12	15	13.4%
	Total	112	100.0%

Table 3-18. Frequency and Percentage of Hours Off prior to Shift 4 (before the First Early Morning Shift) in Participant Work Week Categories 2(a) and 2(b)

Work Week Category	Hours off	Frequency	Percent
(a) xx**E**EE	8	1	4.0%
	9	9	36.0%
	10	10	40.0%
	11-12	5	20.0%
	Total	25	100.0%
(b) xx**E**EM	8	4	30.8%
	9	6	46.2%
	10	3	23.1%
	11-12	0	0.0%
	Total	13	100.0%

The effects of durations of turns less than 12 hours on three dependent measures were assessed: amount of sleep, PVT response speed and PVT lapses. The categorical definitions of quick turns were used for all of these analyses. For each dependent measure, four tests were conducted:

Test #1. Effects of durations of turns less than 12 hours on Day 3 Early shifts: XX**E**E(E/M)
Test #2. Effects of durations of turns less than 12 hours on Day 4 Early shifts: XXX**E**(E/M)
Test #3. Effects on Day 4 Early shifts of durations of turns less than 12 hours versus duration of turns greater than 12 hours: XXX**E**(E/M) versus XXE**E**(E/M)
T*est #4*. Effects of durations of turns less than 12 hours on Day 3 Early shifts versus Day 4 Early shifts: XX**E**E(E/M) versus XXX**E**(E/M)

Effects of Turns of Less than 12 Hours on Sleep Duration. Turn durations of less than 12 hours had no effect on the amount of sleep obtained prior to Day 3 early shifts (Test #1). However, prior to Day 4 early shifts, sleep increased significantly as time off increased from 9 to 10 hours ($p2 = 29.302$, $z(26) = 2.197$, $p = 0.037$), but did not differ between 8 and 9 hours. Sleep duration decreased from 10 hours to 11-12 hours ($p3 = -39.863$, $z(26) = -2.231$, $p = 0.034$) (Test #2). This finding may be due to lack of reliability associated with an $n = 5$ in the 11-12 hour turn condition. When turn durations of less than 12 hours were compared with turn durations of greater than 12 hours, the amount of sleep obtained was greater for the longer time off ($p6 = 49.680$, $z(200) = 5.895$, $p < 0.001$) (Test #3). When Day 3 and Day 4 turns of less than 12 hours were compared (Test #4), the effects of turn durations of less than 12 hours on sleep were no longer significant. The mean total sleep times for each turn duration of less than 12 hours are shown in Table 3-19.

Effects of Turns of Less than 12 Hours on Alertness. Alertness measured by PVT response speed or lapses was not affected by turn durations of less than 12 hours prior to Day 3 early shifts (Test #1). This was not unexpected given that turn duration of less than 12 hours did not affect sleep duration prior to Day 3 early shifts. However, on Day 4, response speeds were slower following a turn of less than 12 hours than a longer duration off (Test #3): (8-12) < (13-15), $p6 = 0.000088$, $z(387) = 2.376$, $p = .018$. Response speed continued to increase marginally when time off increased to 16-18 hours off, $p5 = 0.000082$, $z(387) = 1.679$, $p < 094$. When Day 3 and Day 4 turns of less than 12 hours were compared (Test #4), the effect of turn durations of less than 12 hours was not significant for either response speed or lapses.

Table 3-19. Mean Total Sleep Duration (TSD) and Standard Deviation (S.D.) for each Time Off Duration and Schedule Type prior to Day 3 and Day 4 Early Morning Shifts

DAY 3-E Turns of Less than 12 Hours

Time Off Duration	XXEEE[a]		XXEEM	
	TSD (*n*)	S.D.	TSD (*n*)	S.D.
7 - 8	239.00 (2)	67.88	322.31 (13)	106.75
9	282.38 (8)	49.32	312.87 (*31*)[b]	90.54
10	303.38 (8)	121.46	325.65 (52)	76.52
11-12	-	-	378.50 (*14*)	55.02
13-15	-	-	-	-
16-19	-	-	-	-

DAY 4-E Control

Time Off Duration	XXEEE		XXEEM	
	TSD (*n*)	S.D.	TSD (*n*)	S.D.
7 - 8	-	-	-	-
9	-	-	-	-
10	-	-	-	-
11-12	-	-	-	-
13-15[c]	327.33 (6)	56.29	343.09 (*87*)	89.52
16-19	304.45 (*11*)	80.85	343.33 (24)	74.97

DAY 4-E Turns of Less than 12 Hours

Time Off Duration	XXXEE		XXXEM	
	TSD (*n*)	S.D.	TSD (*n*)	S.D.
7 - 8	263.00 (1)	-	261.75 (4)	27.12
9	286.56 (9)	72.89	264.40 (*5*)	62.97
10	364.89 (*9*)	62.59	290.00 (3)	96.44
11-12	279.60 (5)	68.01	-	-
13-15	-	-	-	-
16-19	-	-	-	-

Notes: [a] Day following turns of less than 12 hours is indicated in red font.
[b] Italicized (*n*) indicates that one case is missing TSD.
[c] These time-off durations are provided as comparisons for Day 4 turns of less than 12 hours.

The only significant and expected effect of turn durations of less than 12 hours on lapses occurred on Day 4 in the comparison of turns less than 12 hours and of turns greater than 12 hours (Test #3). Lapses diminished when time off increased from 13-15 hours to 16-18 hours, p5 = -0.847, z(388) = -2.297, p = 0.022, but there was no significant difference between turns less than 12 hours and turns greater than 12 hours, p6 = -0.155, z(388) = -0.571, p = .568. However, there were two significant unexpected effects: Lapses actually increased with increasing hours off prior to the Day 4 early shifts: from 9 to 10 hours (p2 = 1.135, z(388) = 2.148, p = 0.032) (Test #3) and from 10 to 11-12 hours (p3 = 0.849, z(54) = 2.298, p = 0.025) (Test #2). Similarly, response speed slowed from 9 to 10 hours off, p2 = -0.000193, z(54) = -2.614, p = 0.012 (Test #2). However, these findings are somewhat consistent with findings reported by Nesthus, et al. (2003), who found reduced sleepiness at the beginning of the early morning shift following a 9-hour turn compared to an 8-hour turn, but no continued reduction in sleepiness as the turn increased one more hour to 10 hours off. In addition, negative affect ratings paralleled the sleepiness ratings in the Nesthus, et al. (2003) study: negative affect was lower with the 9-hour turn than with either the 8-hour or 10-hour turn. Nesthus and colleagues interpreted this finding in terms of their low n for the group with 10-hour turn (n = 8) versus those with 9-hour turn (n = 36). That explanation is not relevant to the present findings, as the frequencies of 9 hours off and 10 hours off prior to the early morning shifts were roughly equal (see Tables 3-17 and 3-18).

Some caution is called for in interpreting results from the turn analyses as only a subset of the data were included in the reported analyses. Inclusion of the additional data may clarify the anomalous findings concerning turn durations of less than 12 hours on alertness, especially given the small number of participants contributing to these initial analyses. Also, a parallel analysis is needed to assess the impact of hours off prior to midnight shifts on both sleep duration and alertness. Such an analysis was not conducted initially because of the limited variability in turns of less than 12 hours prior to midnight shifts in the 2-2-1 schedule: 88% were eight or nine hours. This analysis would need to examine other schedule types, such as those in which two midnight shifts occurred in sequence or where the week began with a midnight shift, in order to identify cases with longer durations off prior to the midnight shift.

3.3.5 Subjective Ratings of Sleepiness and Workload

Participants provided a subjective rating of sleepiness after each PVT trial using the Stanford Sleepiness Scale (Hoddes, Zarcone, Smythe, Phillips, & Dement, 1973). Previous research has shown that people are not particularly good judges of their actual levels of fatigue, overestimating their capacity relative to an objective measure (Dorrian, Lamond & Dawson, 2000). However, subjective ratings provide quick and easy indications of perceived capacities and have been used in many prior studies of fatigue, including those previously conducted by CAMI, so they were used as an adjunct measure in this study.

In addition, participants were asked to rate their perceived workload level for the period on position immediately prior to the second and third PVT trials during each shift (the first PVT was taken at the beginning of the work day so no workload rating was available).

3.3.5.1 PVT and Subjective Sleepiness Ratings

The subjective sleepiness rating was found to be positively correlated with lapses, $p_1 = 0.5669$, $p < 0.001$, indicating that the more sleepiness the participant reported, the more lapses were detected on the PVT trial. However, given the sizable number of observations (approximately 4,500) contributing to this effect and hence, the associated statistical power, the correlation of 0.57 is low, accounting for only about 33% of the variance. This suggests that subjective ratings of sleepiness should not be used as a measure of functional alertness without corroboration using other measures.

The relationship between subjective sleepiness ratings and lapses was not moderated by any controller demographic variables.

3.3.5.2 Relationship Between Subjective Workload and Alertness

Participants' subjective workload ratings at the mid-point and at the end of the shift day were compared with lapses during their associated PVT tests. Subjective workload ratings were found to be significantly *negatively* related to number of lapses, $p_1 = -0.1889$, $p = 0.012$, indicating that the higher levels of perceived workload were associated with greater alertness on the associated PVT trial. This result remained when the effect was further examined with the inclusion of the trial and shift variables: more lapses occurred as a work shift progressed, $p_2 = 0.4660$, $p = 0.002$; lapses also increased across shifts of a work week, $p_3 = 0.0855$, $p = 0.010$.

An important question is whether subjective workload varied around the 24-hour clock. In addition to reflecting circadian changes, subjective workload would also be expected to reflect differences in actual traffic loads at various times of the day. To test this possibility, the time of day of each workload rating was entered in the model. Clock time for workload ratings was not significantly correlated with subjective workload, $p_4 = 0.0252$, $p = 0.493$, indicating that workload was not rated lower or higher at any particular time of day.

The relationship between subjective workload rating and lapses was moderated by participant age ($b_{01} = -0.0309$, $p = 0.044$) and years of experience ($b_{02} = 0.0323$, $p = 0.018$), but not by gender ($b_{03} = -0.1935$, $p = 0.122$), when all were entered simultaneously in the model. However, age and years of experience were highly correlated with each other ($r = 0.762$, $p < 0.001$) and thus should not be included in the same model. When entered separately, neither age nor years of experience was a significant moderator, thus suggesting that the age/experience moderator effect was spurious.

3.3.6 Moderator Effects on Controller Sleep

3.3.6.1 Controller Demographics as Moderator Variables

Prior studies have found significant effects of age on tolerance of shiftwork and cognitive alertness (Akerstadt, 1990; Della Rocco & Cruz, 1996 ; Nesthus, et al., 2005). These relationships were examined by using participants' age and years of experience as a controller as moderators of the relationships between schedule factors and duration, efficiency and timing of sleep.

3.3.6.1.1 Controller Demographics and Sleep Duration

The effect of age was examined after the schedule type (i.e., 2-2-1 vs. 2-x-2) and day progression were entered into the model of sleep duration. It was found that age did not have a significant moderating effect on the relationships between sleep duration and schedule type or day progression, $b_{11} = -2.065$, $z(63) = -1.465$, $p = 0.148$, and $b_{21} = -0.086$, $z(63) = -0.317$, $p = 0.752$, respectively. Similarly, years of experience did not have an effect on the relationship between sleep duration and schedule type, $b_{11} = -1.046$, $z(63) = -0.687$, $p = 0.495$, or sleep duration and day progression, $b_{21} = -0.111$, $z(63) = -0.403$, $p = 0.688$. These results imply that neither participant age nor years of experience moderated the effect of schedule type on sleep duration (i.e., the 2-2-1 schedule led to shorter sleep duration than the 2-x-2), nor the progression of work week on sleep duration (i.e., less sleep was obtained as the work week progressed).

3.3.6.1.2 Controller Demographics and Sleep Efficiency

Neither the relationship between sleep efficiency and schedule type nor sleep efficiency and day progression was expected to be moderated because neither relationship was statistically significant. There was no effect of age on the relationship between schedule type and sleep efficiency, $b_{11} = -0.342$, $z(63) = -1.595$, $p = 0.115$. Although no significant relationship between day of week and sleep efficiency was found, there was a marginal moderating effect of age on the relationship, $b_{21} = 0.086$, $z(63) = 1.695$, $p = 0.095$. This pattern of results replicated with years of experience as the moderator: There was no effect of years of experience on the relationship between schedule type and sleep efficiency, $b_{11} = -0.189$, $z(63) = -0.856$, $p = .396$, but a marginal moderating effect of years of experience was measured on the relationship between day of work week and sleep efficiency, $b_{21} = 0.093$, $z(63) = 1.843$, $p = 0.070$. The positive moderating effect of age and years of experience suggests that older or more experienced participants tended to have more constant sleep efficiency (rather than declining) as the work week progressed compared to younger participants, implying that age/years of experience provided some resistance to fatigue. This effect cannot be explained by differences in schedules worked by participants of varying ages and years of experience, as no significant correlation was found between schedule type and participant demographics.

3.3.6.1.3 Controller Demographics and Time Asleep

The relationship between schedule type or day progression and the time at which participants fell asleep were not expected to be moderated because neither relationship was found to be statistically significant. This was confirmed. There was no effect of age on the relationship between schedule type and when participants fell asleep, b_{11} = 10.380, $z(63)$ = 1.189, p = 0.239. No moderation was found on the relationship between day of work week and time to sleep, either, b_{21} = -1.5618, $z(63)$ = -1.112, p = 0.271. Similarly, there was no moderating effect of years of experience on the relationship between schedule type and time to sleep, b_{11} = 9.721, $z(63)$ = 1.091, p = 0.280, nor between day of work week and time to sleep, b_{21} = -2.165, $z(63)$ = -1.528, p = 0.131.

3.3.6.1.4 Controller Demographics and Time Awake

Age did not have an effect on the relationship of time awake with schedule type, b_{11} = -2.607, $z(63)$ = -0.705, p = 0.483, or with day of work week, b_{21} 0.321, $z(63)$ = 0.439, p = 0.662. Similarly, years of experience had no effect on the relationship between schedule type or day of work week and time awake, b_{11} = -0.404, $z(63)$ = -0.107, p = 0.916, and b_{21} = 0.352, $z(63)$ = 0.478, p = 0.634, respectively.

3.3.6.2 Facility Features as Moderators of Controller Sleep

While controllers on average obtained almost six hours of sleep between shifts, those working in different types of facilities obtained significantly different amounts of sleep. Controllers working in TRACONs slept significantly longer (M = 363.94 min or 6.07 hrs) on average than those in En Route Centers (M = 337.76 min or 5.63 hrs), g_{001} = 19.436, $z(24)$ = 2.671, p = 0.014, and those in Towers (M = 344.66 min or 5.74 hrs), g_{001} = 21.501, $z(23)$ = 3.101, p = 0.005.

To determine whether characteristics associated with participating facilities, such as traffic, staffing, and CPC/Developmental ratios, played a role in explaining this difference between facility types, several models were created to include facility characteristics as predictors of sleep duration. It was found that facility traffic level based on the FAA's classification of each facility did not affect the amount of sleep controllers obtained, g_{001} = -2.564, z(24) = -0.519, p = .608. However, both CPC/ Developmental ratio and staffing level affected controller sleep duration when entered individually (due to a moderate negative correlation of -.725 between staffing level and CPC/Developmental ratio), g_{001} = 0.937, $z(24)$ = 2.770, p = 0.011, and g_{001} = -100.332, $z(24)$ = -2.419, p = 0.024, respectively. These results suggest that controllers in facilities with high CPC/Developmental ratios tended to get significantly more sleep than those in facilities with lower CPC/developmental ratios. However, it also was found that controllers in facilities with lower staffing levels tended to sleep more than those in facilities with high staffing levels. This result may have arisen from the moderate correlation between staffing levels and CPC/Developmental ratios. Both models also resulted in non-significant levels of the Level-3 variance component, suggesting that no more variance in sleep duration is available to predict sleep duration at the facility level.

When the facility type and each of the above facility characteristics were included in models together, different patterns of results emerged. First, when CPC/Developmental ratios were considered along with facility type, both effects became statistically non-significant, g_{001} = 0.525, $z(22)$ = 1.221, p = 0.235 for CPC/Developmental ratios, and g_{002} = 13.287, $z(22)$ = 1.514, p = 0.144 for facility type, suggesting that these two variables are related to each other, hence, reducing their individual unique contributions to predicting sleep duration. When staffing level was included along with facility type, staffing was no longer statistically significant, g_{001} = -52.210, $z(22)$ = -0.962, p = 0.347, meaning staffing level did not uniquely predict sleep duration. However, the TRACON to En Route Center comparison remained significant, g_{002} = 15.577, $z(22)$ = 1.936, p = 0.001, confirming that TRACON controllers obtained significantly more sleep than En Route Center controllers, even after controlling for staffing level variations.

3.3.6.3 Facility Features as Moderators of Controller Alertness

No facility level factor uniquely predicted or moderated any of the controller alertness measures or relationships.

3.4 FIELD STUDY SUMMARY AND DISCUSSION

This field study was designed to address several specific questions concerning the impact of controller's shift schedules on the amount of sleep they obtain and their associated alertness on the job. These questions include the following:

1. How much sleep do controllers obtain on average per night and over the entire work week? How do controllers' work schedules influence the amount of sleep they obtain, its timing and efficiency?
2. How do work schedules affect controller alertness during their shifts?
3. Which shifts and schedules are associated with the greatest challenges to controller alertness?
4. Do controller demographics (age, years of experience as a controller, gender) or facility factors affect any of the above findings, either directly or as moderators?
5. How do the present findings compare with findings from previous studies conducted by the FAA's CAMI?
6. What are lessons learned and implications for future fatigue research areas?

Data from 211 participants who participated in the field study and for whom sufficient complete data was available were analyzed to determine the impact of shift schedules on their sleep patterns and alertness. Sleep was characterized in terms of quantity, efficiency and timing, i.e., time asleep and time awake. Alertness was based on objective measures (PVT response speed and lapses, Basner & Dinges, 2011) and subjective ratings using the Stanford Sleepiness Scale (Hoddes, et al., 1973), both obtained three times during each work shift (beginning, middle and late). Findings based on these data were compared to those obtained from our concurrent web-based survey, as well as to earlier studies conducted by researchers at the FAA's CAMI (see Della Rocco & Nesthus, 2005).

3.4.1 Shift Schedules and Controller Sleep

3.4.1.1 Sleep Duration and Shift Schedule Factors

Overall, controllers in the field study obtained almost 6 hours of sleep per night during the work week. This included both their main sleep period plus naps during time off. Variability was quite large because it reflected both the brief sleep periods during the quick turn between the early morning shift and the midnight shift in the 2-2-1 schedule and the longer sleep duration during the RDO prior to the first afternoon shift of the work week.

Controllers obtained the least amount of sleep prior to midnight shifts (mean of 3.3 hours). Sleep prior to early morning shifts also was significantly limited (mean of 5.4 hours), a finding that reflects the start time of shifts beginning between 05:30 and 08:00. To meet those early start times, controllers awoke on average at 04:20. A second factor that may have restricted sleep prior to early shifts is that people entrained to a normal 24-hour clock typically find it difficult to sleep in the evening, when their internal circadian clock still supports alertness (Akerstedt, 1988). To obtain 8 hours of sleep and awaken at 04:20 would mean going to sleep at 20:20 in the evening, before circadian factors typically warrant. Controllers actually went to sleep around 22:30 prior to early shifts, yielding an average of 5.4 hours of sleep.

Total sleep time also varied with the type of schedule worked. When schedule type and day of work week (order) were both entered into our analysis models, both made significant contributions to total sleep time. Controllers slept longer per night on average working the RR schedule with no midnight shift (2-x-2) than those working the 2-2-1 schedule with a midnight shift, consistent with Cruz and Della Rocco (1995). This effect was due to reduced sleep in the 2-2-1 schedule prior to the first early morning shift on Day 3 and the midnight shift on Day 5, both of which were quick turns. Sleep durations on Days

1 and 2 (afternoon shifts) and Day 4 (early shifts) were almost identical in the two schedules, as can be seen in Table 3-12. What this suggests is that the overall mean difference in amount of sleep obtained in the two schedules is driven largely by the shift start times rather than by the schedule.

In addition, both groups slept progressively less per night as they went through their work week. For both groups, work weeks began with afternoon shifts and moved toward early morning shifts, with a midnight shift ending the week for those working a 2-2-1 schedule. In other words, controllers working both schedules began their work weeks with shifts associated with the maximum amount of preparatory sleep (afternoons) and ended with shifts associated with the least amounts of preparatory sleep (early and midnights).

3.4.1.2 Timing of Sleep

Considering the actual times at which participants went to bed and awoke prior to each shift further illuminates the effect of schedule type on total sleep time. The day progression effect was significant for both time asleep and time awake, indicating that controllers went to sleep and arose progressively earlier as the work week advanced. Controllers went to sleep significantly earlier when facing an early morning shift, around 22:30, than they did prior to a mid-day or afternoon shift (asleep between 00:15 and 00:30). This finding does not confirm Cruz and Della Rocco's (1995) finding that controllers went to sleep at roughly the same time each night regardless of the shift start time the next day. Consistent with the Cruz and Della Rocco finding, participants in the present study awoke significantly earlier for the early morning shifts (around 04:30 on average) than for the mid-day or afternoon shifts (between 07:15 and 07:30).

3.4.1.3 Sleep Efficiency

Sleep efficiency was automatically generated from the activity monitor data. Participants were not asked to rate the quality of their sleep, though they did rate how sleepy or alert they felt upon awakening using the Stanford Sleepiness Scale. Actigraphy-based sleep efficiency was significantly lower for naps prior to midnight shifts than for any other sleep periods. Given that this was the shortest sleep period during the work week (average of 3.25 hours), it was expected that sleep efficiency also would be lowest based on a prior CAMI finding that the quality of sleep based on self-rating was commensurate with sleep duration (Nesthus, Cruz, Boquet, Dobbins & Holcomb, 2003).

Despite strong homeostatic pressure to sleep between an early shift and a midnight shift due to limited sleep preceding that early shift and the early awake time, most people find it difficult to sleep during the day, when circadian rhythms are working to keep them alert. Hence, homeostatic and circadian pressures are likely to be in conflict during the quick turn between the early morning and midnight shifts, from around 14:00 to 22:00, resulting in less than fully restful sleep and low sleep efficiency (Torsvall, et al., 1989; Tilley, et al., 1982).

3.4.1.4 Controller Age and Experience as Moderators of Sleep

Neither controller age nor years of experience had a significant effect on the following relationships: amount of sleep and the work week progression, amount of sleep and shift schedule, efficiency of sleep and shift schedule, and time asleep and schedule type. However, both demographic variables moderated the relationship between sleep efficiency and work week progression. As participants aged or there was an increase in the years of experience, they tended to have less efficient sleep as they progress through the work week.

3.4.1.5 Facility Factors as Moderators of Sleep Duration

Because air traffic control facilities differ significantly in factors that were identified as potentially contributing to controller fatigue (DOT OIG, 2009), namely, traffic levels, staffing levels, and amount of time devoted to training developmentals, facilities that varied in these factors were selected for inclusion in the study. Overall, it was found that the overall facility traffic level had no effect on controller sleep, suggesting that staffing was commensurate with the traffic demands. When staffing levels and CPC/Developmental ratios were entered into the model predicting total sleep time (TST) (ignoring facility type), both significantly contributed to TST. However, when entered along with facility type (En Route Center, TRACON, Tower), their contributions were no longer statistically significant.

However, controllers in TRACONS obtained more sleep on average than those in either En Route Centers or Towers. TRACONs had the lowest staffing to target ratio of the three facility types in our study (0.83 vs. 1.00 for Centers and 0.94 for Towers, based on the FAA's low target staffing ranges, FAA, 2009). This low staffing ratio might be expected to result in a greater demand for overtime hours, which could have restricted recovery sleep. Also, TRACONs had a higher CPC to developmental ratio than En Route Centers (4.48 vs. 3.44), which should have proven less fatiguing based on findings from the OIG report (DOT OIG, 2009). The TRACON versus Center comparison for TST remained significant even when staffing levels and CPC/Developmental ratios were also entered in the model. To understand this phenomenon, the actual schedules worked by controllers in the various types of facilities must be examined, given that facility level factors do not seem to explain the effect.

3.4.2 Shift Schedules and Controller Alertness

3.4.2.1 Measuring Alertness with the PVT

Two issues were of concern in selecting the 5-minute PVT as an objective measure of controller alertness, despite its use in other field studies (e.g., Baulk, Fletcher, Kandelaars, Dawson & Roach, 2009). First, 10-minutes is the standard PVT duration that has been widely validated and used in many environments, both field and lab, to detect changes in fatigue as a result of sleep restriction (Basner & Dinges, 2011). There was concern that the 5-minute PVT might not be sufficiently sensitive, given the range of sleep restriction expected among controllers. Some studies using the PVT have shown that response speed slows and lapses increase in the second five minutes of a 10-minute administration compared to the first five minutes (Loh, et al., 2004).

The second concern was that no baseline was available against which to evaluate individual controller performance. In laboratory studies of sleep restriction, measures are typically obtained during a rested baseline period when participants are allowed to sleep 8-10 hours for several days prior to introduction of sleep restriction. Also, large individual differences in vulnerability to the effects of sleep restriction have been reported (Van Dongen, et al., 2004); simply aggregating across subjects could result in high variance that might conceal effects associated with shift schedules.

The solution was to calculate for each 5-minute trial a deviation score from a proxy baseline: the average of the top 10% fastest responses for each participant across the entire 14-day data collection period. Rather than using raw reaction times, response speed (1/RT) was utilized as recommended by Basner and Dinges (2011). In keeping with the literature, lapses were defined as the number of responses slower than 500 ms during the 5-minute trial.

The mean number of lapses was found to be 1.9 per trial. However, the variability was large indicating that on some trials participants' alertness waned considerably, even on that brief trial.

3.4.2.2 Alertness on Midnight Shifts

Midnight shifts in the 2-2-1 schedule posed the greatest challenge to controller alertness, as measured by both PVT response speed and lapses. This finding was predicted because midnight shifts in 2-2-1 schedules suffer from the dual impacts of circadian factors – working when the body normally wants to sleep – and homeostatic pressure to sleep due to restricted sleep during the prior 24 hours. Alertness decrements during midnight shifts may reflect, but are not limited to, the following factors: (a) the quick turn between the prior early morning shift and the midnight shift, typically 8 or 9 hours, during which controllers may commute, eat, interact with family, exercise, and take care of hygiene, all of which leave little time for sleep; (b) circadian factors which interfere with sleep during the day, reducing sleep efficiency and the restorative effects of the sleep; and (c) limited sleep prior to the early morning shift preceding the midnight shift, an average of 5.5 hours. Adding those 5.5 hours to the 2.5 hours obtained on average prior to the midnight shift in the 2-2-1 schedule means that controllers would have had 8 hours of sleep in the prior 24 hours when they begin their midnight shift. However, as pointed out in the discussion of the survey data (see section 2.3.4), by the end of the midnight shift, controllers would be functioning on only 2.5 hours of sleep in the prior 24 hours.

Note that the mean amount of sleep prior to all midnight shifts, regardless of when they occur in a weekly schedule, is 3.25 hours, in contrast to the 2.5 hours of sleep prior to midnight shifts on day 5 of the 2-2-1 schedule. This difference reflects longer durations of pre-midnight sleep when a midnight shift follows any other shift than an early shift, including another midnight shift. Determining the contributions of circadian and homeostatic pressures to the alertness decrements found during the midnight shift in the 2-2-1 schedule would require several targeted comparisons with the 2-2-1 midnight shift: (a) midnight shifts that occur either at the beginning of the work week (day one) following two days of rest; (b) midnight shifts that occur on day five of the work week but do not follow a quick turn, i.e., the prior shift is an A, B, D or M shift; and (c) midnight shifts that do not follow a quick turn, as in (b) but occur on days two, three or four, in order to determine the contribution of cumulative fatigue over the work week on day five midnight shift alertness.

3.4.2.3 Shift Schedules and Alertness

No main effect of schedule type on controller alertness was found, but the comparison in the present study was limited to the 2-2-1 and the 2-x-2 schedules because of the lack of sufficient data associated with other schedules, such as the straight 5-slowly rotating, straight shifts, or 10-hour 4-day schedules. The absence of significant differences in alertness between the two schedule types is not surprising, because both were counter-clockwise rapidly rotating schedules that differed primarily in the presence or absence of a midnight shift on the final day of the week. Other field studies have typically failed to detect significant differences associated with controller work schedules. One exception was the slightly greater increase in choice reaction time (slowing) across days of the week demonstrated by controllers working the 2-2-1 schedule compared to those working a 10-hour 4-day shift schedule (Schroeder, et al., 1995). Despite differences in the mean amount of sleep across the week obtained by controllers working 2-2-1 versus 2-x-2 schedules in both the present study and the Cruz and Della Rocco (1995) study, neither study found significant commensurate effects on alertness, either self-reported or objectively measured.

Both schedules yielded similar patterns of alertness changes across work shifts and the work week: In both alertness declined over the course of a work shift, from trial 1 at the beginning of a shift to trial 3 near the end of the shift, reflected in both PVT response speed and lapses. In addition, the variability of lapses increased over trials, though only from the second trial (around the midpoint of the shift) to the third trial. This finding is in keeping with previous findings of increased instability of alertness measures with increasing fatigue (Doran, Van Dongen, & Dinges, 2001).

Similarly, both the 2-2-1 and 2-x-2 schedules were associated with reductions in alertness across days of the work week, declining significantly from day one to day five, again reflected in both alertness measures. However, the degree to which alertness decreased across the week differed depending on schedule: Greater decrements were found for controllers working the 2-2-1 schedule, which included two quick turns and one midnight shift, compared to the 2-x-2 schedule with no midnight shifts and only one or zero quick turns. Midnight shifts had the greatest impact on alertness, affecting both speed and lapses. Performance also was slower on early morning shifts, but there was no effect on lapses. Both early and midnight shifts occur at the end of the week, raising the question of the source of the apparent “cumulative fatigue“ effect. Further analyses would need to test for changes across days of the work week independent of shift type, such as straight shifts. Prior studies of straight or slowly rotating shifts have shown relatively constant levels of sleep,

3.4.2.4 Recovery Time Between Shifts

The 2-2-1 and 2-x-2 schedules also differ in the frequency and duration of quick turns between rotations, as well as in the total amount of time off between shifts during the work week. Both of these factors affect the opportunity for restorative sleep between shifts. A comparison of the amount of time off between shifts in the two types of schedules is illustrated in Table 3-20.

The first quick turn in the 2-2-1 schedule (left columns) occurs prior to the first early shift on Day 3 (3-E), 9 hours in this example; the first quick turn in the 2-1-2 schedule (right columns) occurs prior to the first early shift on Day 4 (4-E), and is 13 hours. A second quick turn in the 2-2-1 shift between the E and M shifts (5-M) is only 8 hours. There is no corresponding quick turn in the 2-1-2 schedule. Overall, controllers working the illustrated 2-2-1 schedule would have 47 hours off between shifts across the work week, whereas those working the 2-1-2 schedule would have 55 hours off, a difference of 8 hours. In contrast, working a regular 9-to-5 schedule over a 5-day week would provide a total of 64 hours off (16 hours off between each shift). These differences would balance out by the amount of time off on the subsequent regular days off, with the 2-2-1 schedule offering up to 80 consecutive hours off.

Table 3-20. Hours Off between Shifts in a 2-2-1 and a 2-1-2 Schedule

2-2-1 Schedule			**2-1-2 Schedule**		
Shift	Schedule	Hours between Shifts	Shift	Schedule	Hours between Shifts
1-A	15:00–23:00	15	1-A	15:00–23:00	15
2-A	14:00–22:00	9	2-A	14:00–22:00	13
3-E	07:00–15:00	15	3-B	11:00–19:00	12
4-E	06:00–14:00	8	4-E	07:00–15:00	15
5-M	22:00–06:00*		5-E	06:00–14:00	
Total hours off during work week		47	*Total hours off during work week*		55

Note: Shift 5 actually begins at 22:00 on Day 4 and ends on Day 5.

An important question is the extent to which quick turns affect controller alertness. As shown in Table 3-19, longer durations of time off prior to early morning shifts were associated with increased amounts of sleep, but only prior to Day 4, not Day 3. Alertness measured by PVT response speed also improved with increased time off on Day 4.

3.4.2.4.1 *Implications for Fatigue Countermeasures*

The importance of duration of time off between shifts was documented in our models relating the number of hours off between shifts to PVT speed and lapses. Performance suffered the most with eight hours time off[15] and improved as the time off duration increased permitting greater recovery sleep time. Perhaps most important from a countermeasure perspective is the strong relationship between amount of sleep and alertness: the correlation between total sleep duration and lapses was -0.752, accounting for 57% of the variance. This pattern suggests a complex mediating role of amount of sleep between time off and resulting alertness, but this relationship could not be tested using a multilevel modeling approach. What could be tested given the present data set was the impact of duration of time off between shifts on both sleep duration and alertness. The analysis of turns less than 12 hours prior to the early morning shift found that more sleep was obtained as time off increased beyond nine hours, up to 16 hours, but only when the turn of less than 12 hours occurred prior to the fourth shift, not the third shift (the only comparisons our data permitted).[16] This day of week finding suggests an interaction between cumulative fatigue across the work week and the benefits of longer time off. Second, across all shift types (A, B, D, E, M) and schedules, strong significant relationships were found between duration of time off and both measures of alertness (response speed and lapses; see Figures 3-18 and 3-19) when analyzed at the individual level.

3.4.2.4.2 *Individual Differences in Vulnerability to Sleep Loss*

The models in Figures 3-18 and 3-19 illustrate inter-individual differences in vulnerability to time off effects: some controllers were essentially unaffected by restriction of time off, while others showed large effects. In Figure 3-18 (response speed) the topmost value is 0.0 deviation from the fastest 10% of the individual's responses. Hence, a flat or zero slope regression line would mean that individual response speed showed no negative effect of quick turns. Conversely, a sharply sloped line indicates significant impairment (slowing of responses) at the shortest turns and recovery with the longest times off. The lapses shown in Figure 3-19 mirror the speed patterns, with near zero slope lines reflecting an absence of quick turn effects and sharply sloped lines indicating strong effects of quick turn on PVT lapses.

Whether these inter-individual differences in the present study are systematic or random is an open question. However, both age and years of experience were found to moderate the day of week effect on alertness (PVT speed and lapses).

3.4.3 Workload and Alertness

Even though controller alertness measures were not significantly affected by facility level factors that could affect workload, such as traffic levels, staffing levels, or CPC/Developmental ratio, it was important to determine whether workload as perceived by the controllers would have an impact on their alertness. Ratings of workload during the period on position immediately prior to taking each PVT were significantly related to measured alertness: the higher the perceived workload, the higher the alertness measured by PVT performance. This result held even when trial, shift and time of day variables were controlled.

Low workload may be tied to monotony and lead to decreased alertness (Hilburn & Jorna, 2001). This finding is in keeping with a study of monotony that found unstimulating shiftwork to be equivalent to sleep restricted to 4 hours time in bed (Sallinen, et al., 2004). Studies of driver behavior have found that low workload exacerbates fatigue effects, and that drivers perform at higher levels when demands are greater, given similar levels of fatigue (Desmond and Matthews, 1997). Desmond and Hoyes (1996)

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[15] A few quick turns of less than 8 hours reflected early sign in or late sign out during the quick turn.

[16] An anomaly in this pattern was that amount of sleep decreased as hours off increased from 10 hours off to 11-12 hours off, but only five participants contributed to this effect, suggesting it may not be reliable with a larger *n.*

suggested that participants in an air traffic control simulation failed to mobilize their effort effectively when task demands were low versus when they were higher, supporting Hancock and Warm’s (1989) adaptive model of stress and performance.

Several authors caution against confusing fatigue with boredom, both of which may result in reductions in performance (e.g., Soames-Job & Dalziel, 2001). However, boredom arising from task monotony may reflect a drop in motivation rather than a loss of capability, whereas fatigue represents an exhaustion of capability.

3.4.4 Comparison between the Present Field Study and Prior CAMI Studies

The present design replicated an earlier CAMI field study conducted by Cruz and Della Rocco (1995) that compared the 2-2-1 (AAEEM) and the 2-1-2 (AABEE) schedules. Our design expanded the 2-1-2 to include other CCR schedules with no midnight shifts to increase data for analysis in this category; this schedule was defined as 2-x-2 (or AAXEE) to reflect the third shift as either a mid-day (B, as in the 2-1-2), another afternoon (A), a day (D), or an early morning (E) shift. The CAMI study also compared the straight early morning schedule; however, hardly any controllers worked that schedule in the present study sample, so it was not a viable comparison group. (Controllers working midnight shifts were specifically recruited in the present study so the low numbers working straight or slow rotation schedules are to be expected.)

Overall, findings from the present field study were consistent with those from three field studies conducted by CAMI over a decade ago and reported in Cruz and Della Rocco (1995a, 1995b, the Miami Field Study), Nesthus, Cruz, Boquet and Dobbins (2003, the AT-SAFE study), Nesthus, Dattell and Holcomb (2005, the AT-SAFE study), and Schroeder, Rosa and Witt (1998, the 10-hr. vs. 8-hr. Shift Study). Those studies and the present study used similar methods to track sleep and alertness as a function of various controller shift schedules: sleep/activity logs to record amount, timing and quality of sleep, actigraphy to record actual sleep time, self-ratings of sleep quality and alertness/fatigue, and tests of cognitive functioning (Bakan Vigilance test, COGSCREEN or PVT).

The major difference in methods between the CAMI studies and the present one is that the present study used the 5-minute PVT as a simple measure of alertness during each work shift to complement the sleepiness/alertness self-ratings using the Stanford Sleepiness Scale. Besides its brevity, the PVT is insensitive to practice effects, a singular virtue, given the repeated administrations. Some other cognitive tests show significant practice effects, which may distort interpretation of fatigue effects. For example, Banks and colleagues (Banks, et al., 2010) found what appeared to be minimal impact of five days of sleep restriction (4 hours time in bed) on Digit-Symbol Substitution Test accuracy (DSS-T), which could be interpreted as a lack of sensitivity to sleep restriction or absence of sleep restriction effect. However, performance of the non-sleep deprived control group significantly improved over the five days, clearly demonstrating a practice effect on the DSS-T. Also, the PVT and fatigue ratings were done at different times: in the present study PVT and ratings were done at the beginning of each work shift, following the mid-shift break, and following a break near the end of the shift. The CAMI studies typically obtained fatigue ratings at the end of the shift and after the drive home.

Following are specific comparisons of findings from the present field study and earlier CAMI studies. Comparisons of the amount of sleep obtained as a function of shift start times and time off between shifts among the present survey, the present field study and two CAMI field studies are shown in Table 3-21.

Table 3-21. Hours of Sleep Prior to Each Shift Type in the 2010 Survey and Field Study Compared to Two Prior CAMI Field Studies

Shift Type		*2010 Survey* Mean Hours	*2010 Survey* n	*2010 Field Study* Mean Hours	*2010 Field Study* n	*1995 Field Study* [a] Mean Hours	*1995 Field Study* [a] n	*2000 Field Study* (n=71) Mean Hours
Before an afternoon shift (starts between 13:00 and19:59)		7.7	2,987	6.9	327	7.9	16	7.2 [b]
Before a mid-day shift (starts between 10:00 and 12:59)		7.3	2,431	6.8	111	7.6	16	7.7 [b]
Before a day shift (starts between 08:00 and 09:59)		6.7	2,434	6.4	14	-	-	6.5 [b]
Before an early shift (starts before 08:00)		6.3	3,126	5.4	369	5.5	16	5.8 [b]
Before a midnight shift (starts between 20:00 and 01:00)		-	-	3.3 [d]	140	-	-	-
Before a midnight shift after another midnight shift		5.5	1,228	-	-	-	-	-
Before an early shift with…	8-9 hours off	5.4	2,819			5.1	8	
	8-10 hours off			5.2	148			5.4 [c]
	8-12 hours off			5.3	164			
Before a midnight shift with…	8-9 hours off	3.1	1,959			2.4	8	
	8-10 hours off							2.3 [b]
	8-12 hours off			2.5	52			

Note [a] Calculated from Cruz & Della Rocco, 1995a.
[b] Reported in Nesthus, et al., 2001.
[c] Reported in Nesthus, et al., 2003.
[d] The mean hours slept prior to midnight shifts in the field study represents all midnight shifts regardless of duration of time off before the shift.

3.4.4.1 Midnight Shifts

Midnight shifts demonstrated the greatest adverse impact on controller sleep and alertness in our study and the CAMI studies. Prior to midnight shifts controllers working all schedule types in the present study obtained about 3.25 hours of sleep, almost the same as found for the 2-2-1 participants in the 10-hour versus 8-hour shift study, 3.57 hours (Schroeder, 1998). However, participants working a 2-2-1 schedule in the present study only obtained on average 2.35 hours of sleep prior to the midnight shift on day five. This compares with the 2.4 hours of sleep in the Miami study (Cruz and Della Rocco, 1995), the 2.0 hours in the AT-SAFE field study (Nesthus, et al., 2003); and the 2.2 hours reported for 90% of New Zealand air traffic controllers working a rapidly rotating schedule (Signal & Gander, 2007). In the present study measured alertness also was the lowest during the midnight shifts, in agreement with the self-ratings of fatigue in the Cruz and Della Rocco (1995) study and cognitive alertness measures in the AT-SAFE study (Nesthus et al., 2005). Sleep efficiency and self-reported sleep quality also were lowest prior to the midnight shift compared to other shift types in the present study and the prior CAMI studies, thereby perhaps reducing the benefit of the daytime sleep prior to the midnight shift.

3.4.4.2 Early Morning Shifts

Early morning shifts also limited controllers' sleep and alertness. In both the present study and prior CAMI field studies participants arose around 04:20 for early shifts, an hour around most people's circadian lows, and likely before their sleep needs had been completely satisfied. Both studies showed that total sleep time was limited prior to the early morning shift in part because the time at which they went to sleep was not sufficiently early enough to compensate for the early awake time (Cruz & Della Rocco, 1995). However, one difference between the studies was that participants in the present study went to sleep significantly earlier prior to early morning shifts (approximately 22:30) than they did for other shift start times; in the CAMI study participants went to sleep at approximately the same time every night, regardless of shift start time, but then adjusted their awake time to meet the upcoming shift start time. The present study did not include a sufficient number of participants who worked straight-5 early morning shifts to examine their sleep and alertness patterns.

3.4.4.3 Time Off Between Shifts

Turns of less than 12 hours limited the amount of sleep obtained between shifts in both studies, and thereby affected alertness during the subsequent shift. In the present study, turns prior to midnight shifts were eight or nine hours between shifts. Turns prior to the first early morning shift were typically nine to eleven hours between shifts. Both amount of sleep and response speed in the present study were related to duration of time off between shifts, with less sleep and slower responses associate with the shorter (8-9 hour) turns. An unexpected finding in the present study was that the benefits of increasing numbers of hours off prior to an early shift only benefitted sleep and alertness prior to early shifts on day four, not on day three, which occur in the 2-2-1 schedule. This pattern suggests an interaction between cumulative fatigue across days of a work week and opportunities for sleep, but requires validation using the full data set for the present study. In the CAMI studies, amount of sleep, rated sleepiness, sleep quality and mood varied as a function of duration of the time off between shifts (Nesthus et al., 2003; 2005).

3.4.4.4 Cumulative Fatigue within Work Shifts

Both sets of studies found that fatigue accumulated and alertness waned from the beginning to the end of a work shift. This held across all shift start times, but was especially pronounced in midnight shifts. The one exception to this pattern was the 10-hour versus 8-hour field study in which choice reaction time decreased within each of the first four days (Schroeder, et al., 1998). However, errors increased, indicating that performance on this more complex task may reflect a speed-accuracy trade-off. During the midnight shift in the 8-hour. 2-2-1 condition, reaction time and errors both reflected increased fatigue. The proximity to the circadian low after a midnight shift may further increase risk of driving fatigued.

3.4.4.5 Cumulative Fatigue across Days of the Work Week

The CAMI studies and the present study found that fatigue appeared to be cumulative across days in a work week, in compressed schedules. Shifts began earlier each day in the compressed counter-clockwise rapidly rotating schedules. Also, RR schedules rotate toward early morning shifts and a midnight shift in the 2-2-1 and 2-1-2 schedules, which limit sleep and challenge the circadian system. The straight-5 early shifts included in the Cruz and Della Rocco (1995) did not produce significant increases in fatigue across the work week. A question not answered by these analyses is whether this phenomenon is limited to compressed schedules of all types.

3.4.4.6 Sleep Efficiency

Both self-rated sleep quality and the actigraph-generated measure of sleep efficiency (this study) reflected the duration of sleep. Higher quality or more efficient sleep was associated with longer sleep in both studies, regardless of how sleep quality was assessed (Nesthus, et al., 2003; Schroeder, et al., 1998). Lowest efficiency of sleep was associated with naps prior to midnight shifts.

3.4.4.7 Unique Findings in the Present Field Study

3.4.4.7.1 Relation between Workload and Alertness

One measure that was included in the present study but not in prior CAMI studies was perceived workload. Participants were asked to rate on a 7-point scale the workload for their time on position immediately prior to taking the second and third PVT trials during each work shift. These ratings were then correlated with PVT lapses and response speed for that period. A positive relationship was found between workload and alertness: faster responses and fewer lapses were observed when workload was higher, suggesting that higher workload was arousing and engaging, whereas low workload contributed to lower levels of alertness. Hilburn and Jorna (2001) point out that low workload poses as much a threat to controller performance as high workload, based on analysis of controller related incidents and accidents (Redding, 1992; Stager, 1991). Findings from the present study are consistent with those reported in Melton, et al. (1973): Self-reported sleepiness, fatigue and alertness were lowest during the midnight shift, when workload is lowest.

3.4.4.7.2 Day of Shift and Turns Less than 12 Hours

A finding in the present study is the effect of day of the work week on the relation between turn durations of less than 12 hours, sleep and controller alertness. The duration of time off (from 8 hours to 12 hours) had no effect on the amount of sleep controllers obtained or on alertness during the early shift that followed it when the early shift occurred on day three of the work week in an RR schedule, with or without a midnight shift. However, significant effects of turn durations less than 12 hours were found on both amount of sleep and alertness when the turn preceded an early shift on day four of the work week. This finding suggests that cumulative fatigue across the work week may have potentiated the benefits of extra time off for sleep and associated alertness. No tests were done of turns less than 12 hours prior to days two or five due to lack of data. This is a finding that deserves further investigation.

3.4.4.7.3 Influence of Controller Demographics on Sleep and Alertness

Controller age seemed to play a somewhat different role in the CAMI studies and the present study. In CAMI's AT-SAFE field study, older controllers (40 years and older) performed significantly less well than younger controllers on cognitive measures involving speed and working memory (based on COGSCREEN). The adverse effects of quick turns were somewhat greater for older participants, prior to both early morning and midnight shifts in those studies. Similarly, in a laboratory study that simulated a 2-2-1 schedule (with non-controller participants), Della Rocco and Cruz (1996) compared older (50-55 years) and younger (30-35 years) participants' performance on the Multiple Task Performance Battery. While both age groups showed significant decrements in performance during the night shifts, older participants' performance also suffered following the afternoon to early morning quick turn. It should be noted that the 'middle-aged' group (35-50 years) was omitted from this comparison, increasing the likelihood of finding age differences.

In the present study, both age and years of experience as a controller seemed to protect the controllers from cumulative fatigue across the work week, the decline in PVT alertness across the work week was moderated by controller age and years of experience, with older controllers showing less cumulative fatigue on succeeding work days relative to younger controllers.

3.4.4.7.4 Influence of Facility Factors on Controller Sleep and Alertness

Unlike the other field studies conducted by CAMI researchers, the present study solicited participants from a variety of facility types and facilities differing in traffic levels, staffing levels, and CPC/Developmental ratios. None of these factors had significant effects on controllers' sleep quantity or quality or measured alertness, except for one: controllers working in TRACONs obtained more total sleep per day than those in En Route Centers and Towers. No interpretation for this effect is apparent.

3.4.5 Overall Comments

The present study solicited participants who worked midnight shifts, which precluded some comparisons with schedules studied previously by CAMI researchers, such as straight-5s (early morning). Even though controllers who were working midnight shifts were recruited, some of them did not work a midnight shift during the actual data collection period at their facilities. In most cases, those controllers worked schedules that were some variant of the 2-1-2. This meant that it was possible to compare the 2-2-1 and the 2-1-2 schedules as done in the prior CAMI studies. These comparisons involved a reduced *n* of 72, compared to the full *n* of 211 used in our other analyses. The dominant schedule worked by controllers in the present study was the 2-2-1, with 76% of study participants working a 4-day (8%) or 5-day (68%) 2-2-1 schedule. The relatively large *n* in the present study was necessary to assure sufficient power to observe effects—given that participants were from three different types of facilities (En Route, TRACON and Tower) which allowed for a number of factors that could potentially influence controller sleep or alertness. This hierarchical nested data structure also mandated that multilevel modeling be used to analyze the data.

3.4.6 Field Study Conclusions

Findings from the present field study largely confirmed the major patterns of sleep, fatigue and alertness associated with shift schedules found in prior CAMI field studies. The findings confirmed that reduced sleep was associated with early morning and midnight shifts, and that sleep decreased across the work week with commensurate reductions in alertness both across shifts, across the work week, and on midnight shifts. There were a few notable new findings: More sleep was obtained prior to early morning shifts when the time off increased from nine hours to ten hours; overall, less sleep was obtained during turns of less than 12 hours when time off was over 13 hours. However, this effect was only present in turns less than 12 hours prior to early shifts on Day Four compared to Day Three suggesting that the benefits of longer time off are significantly greater later in the work week. This effect may have reflected the fact that controllers working the 2-2-1 schedule adjusted their time asleep to meet the demands of early morning shifts by going to sleep significantly earlier prior to early shifts than later shifts. Participants in the present study also obtained somewhat more sleep prior to midnight shifts averaged across schedules with turns of less than 12 hours and schedules with turns greater than 12 hours.

Overall, the amount of sleep obtained between shifts during the work week was on average less than 6 hours per night. Schedules worked by 76% of controllers in the present study led to what sleep science has defined as chronic fatigue, i.e., restricted amounts of sleep over a number of successive nights (Belenky et al., 2003). Chronic fatigue leads to strong homeostatic pressure to sleep, resulting in very short sleep latencies (i.e., ease of falling asleep).

4. DISCUSSION AND POTENTIAL FAA FUTURE RESEARCH AREAS

The field study and the fatigue survey were developed in close concert to assure that both were addressing in the same key issues of concern to the FAA. Now that results from both studies have been summarized, it is important to review the extent to which the findings are consistent or conflict with each other.

4.1 Integration of Findings from the Fatigue Factors Survey and Field Study

The results from the survey described in Section 2.3 served as the basis for comparison with findings from the field study. The following section is organized in terms of topics taken from the survey summary, followed by results from the field study with notation indicating whether the survey findings were confirmed or not. In many cases, relevant data from the field study are available to address issues raised by the survey, but have not been analyzed. Survey topics that were not addressed by the field study are not mentioned below.

1. SURVEY: Challenge with Midnight Shifts

   Midnight shifts pose a challenge for obtaining sufficient pre-shift sleep and for maintaining alertness, both after quick turns and between successive midnight shifts.

   a. CONFIRMED by Field Study: Mean of only 3.25 hours of sleep was obtained on average prior to midnight shifts; sleep during a quick turn of 8 or 9 hours prior to a midnight shift was only 2.5 hours.
   b. CONFIRMED by Field Study: Participants slept less overall during weeks with counter-clockwise rapidly rotating schedules that included a midnight shift (RRM) than during RR schedules without a midnight shift.
   c. CONFIRMED by Field Study: PVT alertness measures indicated that controllers were least alert ('sharp' in the survey) at the end of the midnight shift.
   d. UNANSWERED by Field Study: Field study did not examine impact of successive midnight shifts on either amount or efficiency of sleep prior to midnight shifts or on measured alertness.

2. SURVEY: Challenge with Early Shifts

   Controllers working early shifts obtained the second least amount of sleep prior to their shift and reported obtaining less sleep than the controllers felt they needed. This was especially an issue after quick turns. Subjective ratings of alertness were the lowest at the beginning of early shifts when compared to all other shifts.

   a. CONFIRMED Indirectly by Field Study: A mean of 5.4 hours of sleep was measured during turns of less than 12 hours prior to early shifts in field study, which is consistent with the total sleep time as reported in the survey.
   b. PARTIALLY CONFIRMED by Field Study: Participants' PVT response speed was significantly slower during the early morning shift than during other shifts, but there was no significant increase in lapses on those shifts.
   c. UNANSWERED by Field Study: Field study did not examine subjective sleepiness at the beginning of shifts, as a function of shift start time or amount of sleep prior to the shift.

3. SURVEY: Quick Turns Restrict Sleep

   Limited time off between shifts restricts the opportunity for recuperative sleep. Sixteen percent of survey respondents reported 8 to 9 hour quick turns; about 25% reported quick turns less than 11 hours. Less sleep was reported prior to both early and midnight shifts during quick turns compared to turns of greater than 11 hours off: 5.4 versus 6.3 hours for early shifts and 3.1 versus 5.5 hours for midnight shifts.

a. CONFIRMED by Field Study: Over 60% of field study participants worked schedules that involved one or more quick turns.[17]

b. CONFIRMED Indirectly by Field Study: Because of the schedules represented in the field study sample, parallel comparisons with survey findings were not possible. No difference in sleep duration was found when comparing sleep prior to all early shifts to early shifts following turns of 12 hours or less (5.4 versus 5.2 hours). But total sleep duration prior to early shifts increased from 9 to 10 hours off, when quick turns of greater than 12 hours were compared to 13-15 hours off, and marginally up to 16-18 hours off, but only when the turn of less than 12 hours occurred prior to day four of the work week, not day three, as occurs in the 2-2-1 schedule. Turns of less than 12 hours prior to midnight shifts (mainly 8-9 hours off) were associated with less than prior to all midnight shifts across all time off durations (2.5 versus 3.25 hours).

4. SURVEY: Alertness and Quick Turns

Alertness was found to be degraded by quick turns between shifts.

a. CONFIRMED Indirectly by Field Study: Lowest objective alertness measured by PVT was found during midnight shifts following turn durations of 12 hours or less. Participants tended to respond more slowly on early morning shifts; however, lapses did not differ from those in later shifts.

b. Partially CONFIRMED by Field Study: Measured alertness confirmed the negative effect of duration of turns less than 12 hours on amount of sleep prior to early morning shifts on Day 4. Significant decrements in alertness were seen with turns of less than 12 hours on both PVT speed and frequency of lapses. Duration of turns less than 12 hours did not affect alertness on Day 3 early shifts. PVT performance was directly related to amount of time off across all shift types. However, no tests were done on other days of the week or for midnight shifts with varying hours off prior to the mid shift. In addition, large individual differences were found in response to quick turns.

5. SURVEY: Schedule Pressure versus Workload

Fatigue is due to schedule pressure, not primarily due to workload.

a. CONFIRMED by Field Study: Higher perceived workload was associated with higher levels of alertness in the field study. No significant effects of variables that might influence workload were found. Individual facility traffic levels, staffing levels and CPC/Developmental ratios had no effect on alertness, most likely due to facility management working to prevent overload conditions. It should be noted that the actual levels and range of workload during the periods of data collection are unknown.

6. SURVEY: Six-Day Schedules

Fatigue was associated with working 6-day schedules with only a single day off. Fourteen percent of survey respondents reported working a 6-day schedule the week prior to taking the survey. Over half of these 6-day schedules included midnight shifts. These schedules were concentrated in TRACONs.

a. CONFIRMED by Field Study: Over 21% of the work weeks analyzed consisted of 6-day work schedules during the study period (this trend should not be taken as representative of all controller schedules).

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[17] This high rate reflects the participant solicitation criterion of working at least one midnight shift per week, which assured at least one quick turn.

b. CONFIRMED by Field Study: Over 68% of the 6-day schedules involved one or more midnight shifts (this figure should not be taken as representative of controller schedules as controllers who worked midnight shifts were actively recruited).

c. UNANSWERED by Field Study: No analyses were conducted on 6-day schedules, with or without midnight shifts, to compare sleep duration, timing and efficiency with that obtained during normal 5-day or shorter 4-day work weeks. Sufficient data for such analyses appear to be available.

d. UNANSWERED by Field Study: No analyses were conducted to determine whether alertness in field study participants was affected by working 6-day schedules, with or without midnight shifts. Sufficient data for such analyses appear to be available.

7. SURVEY: TRACON Schedules and Staffing

Survey responses indicated that 6-day schedules and mandatory overtime were disproportionately concentrated in TRACONs relative to En Route Centers or Towers. Respondents also reported that they felt staffing was less than adequate in TRACONs.

a. CONFIRMED by Field Study: Six-day schedules were over-represented in TRACONs at 38% of all schedules, compared to 12% for Towers and 17% for En Route Centers.

b. CONFIRMED by Field Study: A comparison of current staffing levels to recommended target staffing levels based on the FAA's Ten-Year Staffing Plan (FAA, 2009) shows that the 11 TRACONs that participated in the field study were all somewhat below parity, based on the lower bound of the target range. The mean actual-to-target ratio for all participating TRACONs was 0.83, with a range of 0.60 to 0.97. In contrast, the mean staffing ratio for En Route Centers was 1.0 (range from 0.90 to 1.18) and for Towers the mean ratio was 0.94 (range from 0.76 to 1.35). See Table 3.1 for detail. While facilities were selected based on a range of diverse characteristics, facilities with low staffing levels were not deliberately selected.

8. SURVEY: Age and Working Midnight Shifts

The survey indicated a slightly greater proportion of older controllers than younger ones working midnight shifts, including 6-day weeks containing midnights. In addition, no higher incidence of operational events was associated with older age, despite their working more midnights.

a. PARTIALLY CONFIRMED by Field Study: Since practically all of the field study participants worked midnight shifts, there was a disproportionate representation of older controllers working midnights. No significant relationship was found between age and schedules worked. Age moderated the effect of increasing fatigue across work days, with older participants showing a smaller increase in PVT lapses. Years of experience working as a controller had a similar effect.

9. SURVEY: Staffing Levels and Fatigue

Survey respondents reported their view that low workload promotes greater fatigue, and that low workload is tied to some positions being overstaffed during low workload periods. They recommended not overstaffing positions during low workload periods.

a. Partially CONFIRMED by Field Study: A positive relationship was found between perceived workload and measured alertness. Alertness as measured by the PVT was greater following on-position periods rated as higher workload by the field study participants, but no information was available concerning staffing during those shifts.

4.2 Unanswered Questions

Several unexpected findings from the survey raised questions that the field study design had not anticipated; hence, no effort had been made to select participants and schedules to address those issues. In some cases, limited data may be available in the present field study dataset to address these issues. Given the implications for FAA policy associated with several of the issues, it is important to identify them so that future research can address them.

- *Effects of quick turns on alertness during midnight shifts.* Analyses are needed to examine the impacts of circadian factors associated with working midnight shifts (circadian lows), quick-turn restrictions on sleep opportunities prior to midnights, and day of week effects. In the current field study these factors are confounded in midnight shifts that occur on Day 5 of 2-2-1 schedules.

- *Impact of amount of sleep in prior 24 hours before a midnight shift.* Relating to the first point, further analysis is needed to assess the impact of amount of sleep during the 24-hour and 48-hour periods preceding a midnight shift.

- *Impact of working 6-day schedules.* Six-day schedules proved to be the least preferred schedule type by survey respondents. Controllers in both the survey and field study samples worked a 6-day schedule during the study period. The impact on controller alertness of one or more 6-day weeks in a row is unknown and should be investigated. The field study data may begin to address this issue.

- *Impact of working multiple midnight shifts.* Many of the schedules reported by survey respondents involved more than one midnight shift. The field study also found a number of 5- and 6-day schedules that included more than one midnight shift, usually back-to-back. Fatigue related impacts resulting from working multiple midnight shifts should be investigated. The field study data may begin to address this issue.

- *Interactions between shift start times and days of a work week.* The finding of cumulative fatigue over the course of a work week is widely reported, but these findings are often confounded with the nature of the schedule. For example, the counter-clockwise rapid rotating schedules typically include an early morning shift or midnight shift at the end of the work week. Both of these shifts are associated with reduced sleep duration and lower alertness levels than other shifts. The benefits of longer time off between shifts found in the field study were restricted to Day 4 and not evident on Day 3 suggesting a possible interaction between day of the week and need for sleep. This issue deserves a more detailed assessment in order to design schedules that optimize alertness and performance.

- *Impact of interrupted work weeks on alertness.* An unexpected pattern seen in the present field study was the ‘interrupted’ work week— 5- or 6-day work weeks that followed known schedule patterns (e.g., 2-2-1, 2-1-2, 2-3, etc.) and were interrupted by a day off. The frequency of these schedules and impact of these interrupted schedules on sleep and alertness are completely unknown.

4.3 Potential Future Research Areas

The FAA is developing a Fatigue Risk Management System that may address many of the challenges identified by the present study. In addition, some policies have already been changed to support opportunities for increased restorative sleep. The following future research areas, which are based on findings from the present studies, have been identified as follows:

1. Investigate the scientific effectiveness and operational feasibility of

a) adjusting shift start times for the shift preceding the midnight shift to build up sleep reserve before the midnight shift and

b) increasing the minimum numbers of hours off (currently 9) between afternoon and morning shifts to allow for longer recovery sleep opportunities (FAA, 2012).

2. Continue the development of the Fatigue Risk Management System supported by NATCA and the FAA. Important areas of collaboration are to

   a) investigate the circumstances requiring 6-day work schedules and ways to reduce the frequency of 6-day work schedules (i.e., those with mandatory overtime),

   b) consider ways to alleviate challenges associated with both scheduling and staffing at TRACONs,

   c) assess and manage workload and overtime hours of Front Line Managers,

   d) investigate the availability and the impacts on fatigue of 10-hour 4-day schedules, and

   e) investigate and monitor fatigue safety culture.

3. Consider developing and/or providing support tools that

   a) support standardized classification of workforce schedules,

   b) identify potential schedules that may contribute to fatigue,

   c) support day-to-day scheduling that interfaces with predicted weather and traffic levels, and

   d) assist FLMs in staffing to traffic during shifts that minimizes fatigue effects.

4. Continue to develop and/or clarify existing policy related to encouraging controllers to seek diagnosis and treatment of sleep disorders.

5. Enhance training material on fatigue and its management for the controller workforce and for FLMs.

6. Continue periodic surveys and targeted field studies by independent investigators to

   a) assess the effectiveness of air traffic fatigue risk interventions ,

   b) assess schedules, fatigue factors and alertness levels, and

   c) solicit suggestions from ATC personnel on ways to reduce controller fatigue.

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Appendix A. NASA ATC Fatigue Factors Survey

NASA ATC Fatigue Factors Survey

Ames Research Center

This survey will help NATCA and the FAA understand fatigue in the air traffic controller work force. It will gather controller inputs on factors that contribute to workplace fatigue, such as shift schedules, sleep patterns and workplace experiences.

Your input will be analyzed by NASA Ames Research Center and that analysis will be used by the joint NATCA and FAA Fatigue Risk Management Work Group to help develop ways to reduce fatigue risk to the ATC workforce and the NAS.

This survey is anonymous, and all data will be protected in accordance with NASA's privacy policy, so please feel free to be candid with your responses. The survey will take about 35 minutes to complete.

Your input in this research effort is extremely valuable, and so your participation is very much appreciated.

If you have any questions or issues related to completing the survey please feel free to contact Bonny Parke at the NASA Ames Research Center.

Bonny Parke, Ph. D.
Bonny.Parke@nasa.gov
(650) 604-2716

Schedule Overview

All times in this survey refer to a 24-hour day from 0000 to 2359.

1. In general, about how many hours a week do you work--including overtime?

- [ ] 20 or less
- [ ] 21-25
- [ ] 26-30
- [ ] 31-35
- [ ] 36-39
- [ ] 40
- [ ] 41-45
- [ ] 46-50
- [ ] 51-55
- [ ] over 55

2. Do you work an administrative schedule, that is, standard business hours (between the hours of 0700 and 1800), 5 days a week?

- [ ] Yes
- [ ] No

If YES, skip to question #18

3. Do you work midnight shifts as part of your bid schedule (start between 2000 and 0100)?

- [ ] Yes
- [ ] No

If yes, how are they organized?

- [ ] One midnight shift each week
- [ ] One midnight shift every other week
- [ ] A few midnight shifts per year
- [ ] A single block of midnight shifts per year
- [ ] Occasional blocks of midnight shifts per year
- [ ] A block of midnight shifts every 3-4 weeks
- [ ] Permanent midnight shifts
- [ ] Other

If other, please describe.

____

4. About how many midnight shifts do you actually work in a month?

- [ ] 0 or <1/mo
- [ ] 1
- [ ] 2
- [ ] 3
- [ ] 4
- [ ] 5
- [ ] 6-8
- [ ] 9-12
- [ ] 13-16
- [ ] 17+

5. Typically, about how many very quick turn-arounds with only <u>8 or 9 hours</u> between the end of one shift and the beginning of another, do you work per week?

- [ ] None
- [ ] 1
- [ ] 2
- [ ] 3
- [ ] 4

6. Typically, about how many very quick turn-arounds with only <u>10-11 hours</u> between the end of one shift and the beginning of another, do you work per week?

- [ ] None
- [ ] 1
- [ ] 2
- [ ] 3
- [ ] 4

7. Do your Regular Days Off (RDOs) rotate to different days from week to week?

- [ ] Yes
- [ ] No

Bid Schedule

Please describe your bid schedule for a 1-week period. If you work two shifts in one day (e.g. a morning and a midnight shift), please also describe the second shift. If your schedule differs from week to week, please continue describing it in the next table.

8.

	1st shift start time (24-hour day from 0000 to 2359)	Hours on shift (hours & minutes, e.g., 7.5 hours = 0730)	2nd shift start time (24-hour day from 0000 to 2359)	Hours on shift (hours & minutes, e.g., 7.5 hours = 0730)
Sun				
Mon				
Tues				
Wed				
Thurs				
Fri				
Sat				

If your schedule differs over a 2 or 3-week period, please continue describing your work schedule.

Week 2

9.

	1st shift start time (24-hour day from 0000 to 2359)	Hours on shift (hours & minutes, e.g., 7.5 hours = 0730)	2nd shift start time (24-hour day from 0000 to 2359)	Hours on shift (hours & minutes, e.g., 7.5 hours = 0730)
Sun				
Mon				
Tues				
Wed				
Thurs				
Fri				
Sat				

Week 3

10.

	1st shift start time (24-hour day from 0000 to 2359)	Hours on shift (hours & minutes, e.g., 7.5 hours = 0730)	2nd shift start time (24-hour day from 0000 to 2359)	Hours on shift (hours & minutes, e.g., 7.5 hours = 0730)
Sun				
Mon				
Tues				
Wed				
Thurs				
Fri				
Sat				

11. If you cannot completely represent your work schedule in the above tables, please describe it below.

Schedule Actually Worked in the Last Full Week

Please describe the schedule you ACTUALLY worked in the last full week from Sunday to Saturday, including overtime hours worked. If you worked two shifts on one day (e.g. a morning and a midnight shift), please also describe the second shift. If you were on vacation, please describe the last full week you worked.

12.

	1st shift start time (24-hour day from 0000 to 2359)	Hours worked (hours & minutes, e.g., 7.5 hours = 0730)	How many of these hours were overtime? (hours & minutes)
Sun			
Mon			
Tues			
Wed			
Thurs			
Fri			
Sat			

13.

	2nd shift start time (24-hour day from 0000 to 2359)	Hours worked (hours & minutes, e.g., 7.5 hours = 0730)	How many of these hours were overtime? (hours & minutes)
Sun	☐☐☐☐	☐☐☐☐	☐☐☐☐
Mon	☐☐☐☐	☐☐☐☐	☐☐☐☐
Tues	☐☐☐☐	☐☐☐☐	☐☐☐☐
Wed	☐☐☐☐	☐☐☐☐	☐☐☐☐
Thurs	☐☐☐☐	☐☐☐☐	☐☐☐☐
Fri	☐☐☐☐	☐☐☐☐	☐☐☐☐
Sat	☐☐☐☐	☐☐☐☐	☐☐☐☐

16. If you worked any overtime hours in this week, how many of these hours were both required and on short notice (i.e. unscheduled).

☐ 0 ☐ 3-4 ☐ 7-8 ☐ 11-12 ☐ 15 and over
☐ 1-2 ☐ 5-6 ☐ 9-10 ☐ 13-14

17. Comments

☐

Workload-related Fatigue

On-the-Job-Training (OJT)

18. Are you working as a Certified Professional Controller (CPC)?

☐ Yes ☐ No

If yes, about how many hours a week, if any, do you typically give OJT?

☐ 0 ☐ 5-9 ☐ 15-19 ☐ 25 & over
☐ 1-4 ☐ 10-14 ☐ 20-24

19. Are you working as a developmental?

☐ Yes ☐ No

If yes, about how many hours a week, if any, do you typically receive OJT?

☐ 0 ☐ 5-9 ☐ 15-19 ☐ 25 & over
☐ 1-4 ☐ 10-14 ☐ 20-24

If you working as a developmental, are you currently certified on one or more positions?

☐ Yes ☐ No ☐ N/A

Workload/Staffing

20. I can comfortably keep up with my workload.

N/A	Never	Rarely	Sometimes	Usually	Always
☐	☐	☐	☐	☐	☐

21. There are enough qualified controllers on my shifts to do the work safely.

N/A	Never	Rarely	Sometimes	Usually	Always
☐	☐	☐	☐	☐	☐

Combined Positions

22. When I work a combined position, I believe it should be decombined.

N/A	Never	Rarely	Sometimes	Frequently	Usually
☐	☐	☐	☐	☐	☐

23. When working a combined position that I believe should be decombined,

	N/A	Never	Rarely	Sometimes	Frequently	Usually
I feel comfortable asking that it be decombined.	☐	☐	☐	☐	☐	☐
There is enough staffing to enable it to be decombined.	☐	☐	☐	☐	☐	☐
My supervisor would decombine a position if I requested it and staffing permitted.	☐	☐	☐	☐	☐	☐

Support Personnel

24. I work without a support person when I feel I need one (e.g. a radar associate or handoff controller).

N/A	Never	Rarely	Sometimes	Frequently	Usually
☐	☐	☐	☐	☐	☐

25. When I feel I need a support person,

	N/A	Never	Rarely	Sometimes	Frequently	Usually
I feel comfortable requesting one.	☐	☐	☐	☐	☐	☐
There is enough staffing to enable a support person.	☐	☐	☐	☐	☐	☐
My supervisor would provide a support person if I requested one and staffing permitted.	☐	☐	☐	☐	☐	☐

Fatigue

26. When I am fatigued at work,

	N/A	Never	Rarely	Sometimes	Frequently	Usually
I feel comfortable asking for a break or rotation.	☐	☐	☐	☐	☐	☐
There is enough staffing to allow a break or rotation.	☐	☐	☐	☐	☐	☐
My supervisor would provide a break or rotation if I requested one and staffing permitted.	☐	☐	☐	☐	☐	☐

Rotation and Breaks

27. In general, are positions adequately rotated to reduce work-related fatigue where you work?

N/A	Not at all adequate	-	Somewhat adequate	-	Extremely adequate
☐	☐	☐	☐	☐	☐

28. On average, about how long are your breaks (non-meal)?

- ☐ N/A
- ☐ Under 10 minutes
- ☐ 10-19 minutes
- ☐ 20-29 minutes
- ☐ 30-39 minutes
- ☐ 40-49 minutes
- ☐ 50-59 minutes
- ☐ 60+minutes

29. On average, how frequently do you have breaks when you are on position?

- ☐ N/A
- ☐ Every 30 min. or less
- ☐ Every 45 min.
- ☐ Every 1 hr.
- ☐ Every 1 hr. 15 min.
- ☐ Every 1 hr. 30 min.
- ☐ Every 1 hr. 45 min.
- ☐ Every 2 hrs.
- ☐ Every 2 hrs. 15 min.
- ☐ Every 2 hrs. 30 min. or more

30. Do you feel that more breaks could be safely taken during low workload periods?

- ☐ Yes
- ☐ No
- ☐ N/A / Don't Know

31. If yes, about how often do these low workload periods (where breaks could safely be taken) occur during your typical week?

N/A or Don't know	1-2 times a week	3-4 times a week	5-6 times a week	7-8 times a week	Over 8 times a week
☐	☐	☐	☐	☐	☐

32. How often do you feel you need a break in the following circumstances?

	N/A	After 1/2 hr.	After 1 hr.	After 1 1/2 hrs.	After 2 hrs.
When traffic is light or workload is low	☐	☐	☐	☐	☐
When traffic is busy or workload is high	☐	☐	☐	☐	☐
When providing or receiving OJT instruction	☐	☐	☐	☐	☐

33. Please indicate the extent to which you feel the following factors are currently at about the right level to support your optimal alertness.

	N/A	Not nearly enough	Not enough	About right	Too much	Way too much
Length of breaks (non-meal)	☐	☐	☐	☐	☐	☐
Length of time between breaks (non-meal)	☐	☐	☐	☐	☐	☐
Rotation of positions	☐	☐	☐	☐	☐	☐
CPC staffing levels	☐	☐	☐	☐	☐	☐
Hours providing or receiving on-the-job training	☐	☐	☐	☐	☐	☐
Number of hours worked	☐	☐	☐	☐	☐	☐
Overall workload	☐	☐	☐	☐	☐	☐
Traffic volume	☐	☐	☐	☐	☐	☐
Traffic complexity	☐	☐	☐	☐	☐	☐

34. Comments

Stress-related Fatigue

34. In general, how stressed do you feel at work?

Not at all	-	Somewhat	-	Very much
☐	☐	☐	☐	☐

If stressed, to what extent do you feel that the following contribute to your stress?

	Not at all	-	Somewhat	-	Very much
Relations with co-workers	☐	☐	☐	☐	☐
Relations with supervisors	☐	☐	☐	☐	☐
Upper management decisions	☐	☐	☐	☐	☐
Workload	☐	☐	☐	☐	☐
Responsibility for aviation safety	☐	☐	☐	☐	☐
Work schedule	☐	☐	☐	☐	☐
Work/life balance	☐	☐	☐	☐	☐
Other	☐	☐	☐	☐	☐

If other, please describe.

Additional Activities

35. How do you usually get to and from work?

☐ Drive alone ☐ Car pool ☐ Take public transportation ☐ Other

If other, please describe.

36. How many minutes is your average one-way commute time to work?

	N/A	1-15	16-30	31-45	46-60	61-75	76-90	91-105	106-120	121+
Early shifts (i.e., start before 0800)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Day shifts (i.e., start between 0800 & 0959)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Mid-day shifts (i.e., start between 1000 & 1259)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Afternoon shifts (i.e., start between 1300 & 1959)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Midnight shifts (i.e., start between 2000 & 0100)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

37. Do you live in a low or high cost-of-living area?

Extremely low	Somewhat low	About average	Somewhat high	Extremely high
☐	☐	☐	☐	☐

38. Do you have a second paid job in addition to your FAA job?

☐ Yes ☐ No

If so, for about how many hours a week?

☐ N/A ☐ 5-9 ☐ 15-19 ☐ 25-29
☐ less than 5 ☐ 10-14 ☐ 20-24 ☐ 30+

39. Comments

Sleep Schedule

On the shifts that you work, please indicate the times you typically go to sleep before that shift, and about how many hours you sleep. "Very quick turn-arounds" refer to shift rotations with 9 or fewer hours between them.

40. Go to sleep before shift (24-hour day from 0000 to 2359)

Before an early shift (starts before 0800)	☐☐☐☐
Before an early shift after a very quick turn-around	☐☐☐☐
Before a day shift (starts between 0800 & 0959)	☐☐☐☐
Before a mid-day shift (starts between 1000 & 1259)	☐☐☐☐
Before an afternoon shift (starts between 1300 & 1959)	☐☐☐☐
Before a midnight shift (starts between 2000 & 0100) after a very quick turn-around	☐☐☐☐
Before a midnight shift after another midnight shift	☐☐☐☐

Hours typically slept (hours & minutes, e.g., 7.5 hours = 0730)

Before an early shift (starts before 0800)	☐☐☐☐
Before an early shift after a very quick turn-around	☐☐☐☐
Before a day shift (starts between 0800 & 0959)	☐☐☐☐
Before a mid-day shift (starts between 1000 & 1259)	☐☐☐☐
Before an afternoon shift (starts between 1300 & 1959)	☐☐☐☐
Before a midnight shift (starts between 2000 & 0100) after a very quick turn-around	☐☐☐☐
Before a midnight shift after another midnight shift	☐☐☐☐

41. Go to sleep 2nd time before shift, if applicable (24-hour day from 0000 to 2359)

Before an early shift (starts before 0800)	☐☐☐☐
Before an early shift after a very quick turn-around	☐☐☐☐
Before a day shift (starts between 0800 & 0959)	☐☐☐☐
Before a mid-day shift (starts between 1000 & 1259)	☐☐☐☐
Before an afternoon shift (starts between 1300 & 1959)	☐☐☐☐
Before a midnight shift (starts between 2000 & 0100) after a very quick turn-around	☐☐☐☐
Before a midnight shift after another midnight shift	☐☐☐☐

Hours typically slept 2nd time, if applicable (hours & minutes, e.g., 7.5 hours = 0730)

Before an early shift (starts before 0800)	
Before an early shift after a very quick turn-around	
Before a day shift (starts between 0800 & 0959)	
Before a mid-day shift (starts between 1000 & 1259)	
Before an afternoon shift (starts between 1300 & 1959)	
Before a midnight shift (starts between 2000 & 0100) after a very quick turn-around	
Before a midnight shift after another midnight shift	

42. Please indicate your sleep schedules on relevant RDOs (regular days off).

	Go to sleep during day (0000 to 2359)	Hours typically slept (hours & minutes)
RDOs AFTER midnight shift		
On other RDOs		

	Go to sleep at night (0000 to 2359)	Hours typically slept (hours & minutes)
RDOs AFTER midnight shift		
On other RDOs		

43. Comments

Naps

Naps are brief sleeps in addition to your main sleep. Naps can range from a brief sleep at home in bed, to a brief sleep obtained while resting one's head on a table in a break room.

44. In the last year, have you felt like you needed to take a nap during breaks at work?

☐ Almost never ☐ Rarely ☐ Sometimes ☐ Often ☐ Almost always ☐ N/A

45. Do you feel that naps taken on breaks at work would increase your alertness at work?

☐ Yes ☐ No ☐ N/A / Don't Know

46. If yes, on which shift(s) would naps be of most benefit? (Select all that apply.)

☐ Early shift (shift starts before 0800)
☐ Day shift (shift starts before 0800 & 0959)
☐ Mid-day shift (shift starts between 1000 & 1259)
☐ Afternoon shift (shift starts between 1300 & 1959)
☐ Midnight shift (shift starts between 2000 & 0100)

47. Comments

Sleep Quality & Shifts

48. How rested do you normally feel after sleep. . .

	N/A	Definitely not rested	Not very rested	Moderately rested	Quite rested	Extremely rested
between successive early shifts (shift starts before 0800)?	☐	☐	☐	☐	☐	☐
before early shifts after a very quick turn-around (9 hours or less) from an afternoon shift?	☐	☐	☐	☐	☐	☐
between successive day shifts (shift starts between 0800 & 0959)?	☐	☐	☐	☐	☐	☐
between successive mid-day shifts (shift starts between 10 & 1259)?	☐	☐	☐	☐	☐	☐
between successive afternoon shifts (shift starts between 1300 & 1959)?	☐	☐	☐	☐	☐	☐
between successive midnight shifts (shift starts between 2000 & 0100)?	☐	☐	☐	☐	☐	☐
before midnight shifts after a very quick turn-around (9 hours or less) from an early shift?	☐	☐	☐	☐	☐	☐
between successive days off?	☐	☐	☐	☐	☐	☐
on the last night of your RDOs?	☐	☐	☐	☐	☐	☐

Sleep Patterns During Your Work Week

49. How rested do you normally feel after sleep. . .

	Never	Rarely	Sometimes	Frequently	Usually
Do you awaken earlier than you want to?	☐	☐	☐	☐	☐
Do you awaken in the middle of your sleep period?	☐	☐	☐	☐	☐
Are you unable to sleep when you want to?	☐	☐	☐	☐	☐
Do you drink alcohol in the hour before you sleep?	☐	☐	☐	☐	☐

50. About how many servings of caffeine (e.g., coffee, tea, soda, energy drinks, NoDoz, etc.) do you typically have in a 24-hour period?

☐ 0
☐ 1-2
☐ 3-4
☐ 5-6
☐ 7-8
☐ 9-10
☐ 11+

51. **Do you feel you have trouble sleeping for any of the following reasons? (Check all that apply.)**

- ☐ Shift work
- ☐ Keyed up, can't relax
- ☐ Gastrointestinal problems
- ☐ Sleep disorders
- ☐ Other health issues
- ☐ Amount of caffeine ingested
- ☐ Desire to smoke
- ☐ Need to urinate
- ☐ Hunger
- ☐ Worry/anxiety
- ☐ Disturbed by partners/children/pets
- ☐ Other outside noise, light, temperature, etc.
- ☐ Other

If other, please describe.

52. **If you were allowed to take over-the-counter or prescribed medications to help you sleep, would you?**

- ☐ Yes
- ☐ No
- ☐ Don't know

53. **About how many hours of sleep do you feel you need in a 24-hour period, irrespective of which shift you are on?**

- ☐ less than 5
- ☐ 5-6
- ☐ 6-7
- ☐ 7-8
- ☐ 8-9
- ☐ 9-10
- ☐ 11 or more

54. Comments

Alertness

Please rate how mentally sharp (e.g., alertness, memory) you would be at the BEGINNING and END of each of the following shifts that you work. "Very quick turn-arounds" refer to shift rotations with 9 or fewer hours between them.

55. Beginning of Shift

	N/A	Not at all sharp	-	-	-	Very sharp
Early shifts (start before 0800)	☐	☐	☐	☐	☐	☐
Early shifts after a very quick turn-around	☐	☐	☐	☐	☐	☐
Day shifts (start between 0800 & 0959)	☐	☐	☐	☐	☐	☐
Mid-day shifts (start between 1000 & 1259)	☐	☐	☐	☐	☐	☐
Afternoon shifts (start between 1300 & 1959)	☐	☐	☐	☐	☐	☐
Midnight shifts (start between 2000 & 0100)	☐	☐	☐	☐	☐	☐
Midnight shifts after a very quick turn-around	☐	☐	☐	☐	☐	☐

56. End of Shift

	N/A	Not at all sharp	-	-	-	Very sharp
Early shifts (start before 0800)	☐	☐	☐	☐	☐	☐
Early shifts after a very quick turn-around	☐	☐	☐	☐	☐	☐
Day shifts (start between 0800 & 0959)	☐	☐	☐	☐	☐	☐
Mid-day shifts (start between 1000 & 1259)	☐	☐	☐	☐	☐	☐
Afternoon shifts (start between 1300 & 1959)	☐	☐	☐	☐	☐	☐
Midnight shifts (start between 2000 & 0100)	☐	☐	☐	☐	☐	☐
Midnight shifts after a very quick turn-around	☐	☐	☐	☐	☐	☐

Please rate how mentally sharp (e.g., alertness, memory) you would be at the END of various times on position during light traffic and during a heavy push.

57. Light Traffic

	N/A	Not at all sharp	-	-	-	Very sharp
After being on position for 1/2 hr.	☐	☐	☐	☐	☐	☐
After being on position for 1hr.	☐	☐	☐	☐	☐	☐
After being on position for 1 1/2 hrs.	☐	☐	☐	☐	☐	☐
After being on position for 2 hrs.	☐	☐	☐	☐	☐	☐

58. A Heavy Push

	N/A	Not at all sharp	-	-	-	Very sharp
After being on position for 1/2 hr.	☐	☐	☐	☐	☐	☐
After being on position for 1hr.	☐	☐	☐	☐	☐	☐
After being on position for 1 1/2 hrs.	☐	☐	☐	☐	☐	☐
After being on position for 2 hrs.	☐	☐	☐	☐	☐	☐

59. In the last year, have you caught yourself about to "doze off" during work duties?

☐ Yes ☐ No

60. If yes, how often has this occurred on the following shifts?

	N/A	Never	Rarely	Sometimes	Frequently	Usually
Early shifts (start before 0800)	☐	☐	☐	☐	☐	☐
Early shifts after a very quick turn-around	☐	☐	☐	☐	☐	☐
Day shifts (start between 0800 & 0959)	☐	☐	☐	☐	☐	☐
Mid-day shifts (start between 1000 & 1259)	☐	☐	☐	☐	☐	☐
Afternoon shifts (start between 1300 & 1959)	☐	☐	☐	☐	☐	☐
Midnight shifts (start between 2000 & 0100)	☐	☐	☐	☐	☐	☐
Midnight shifts after a very quick turn-around	☐	☐	☐	☐	☐	☐

61. In the last year, have you caught yourself about to "doze off" on a break after . . .

	N/A	Never	Rarely	Sometimes	Frequently	Usually
light traffic?	☐	☐	☐	☐	☐	☐
a heavy push?	☐	☐	☐	☐	☐	☐

62. How likely are you to doze off or fall asleep in the following non-work situations in recent months, in contrast to just feeling tired?

	No chance of dozing	Slight chance of dozing	Moderate chance of dozing	High chance of dozing
Sitting and reading	☐	☐	☐	☐
Watching TV	☐	☐	☐	☐
Sitting inactive in a public place (e.g., a theater or a meeting)	☐	☐	☐	☐
As a passenger in a car for an hour without a break	☐	☐	☐	☐
Lying down to rest in the afternoon when circumstances permit	☐	☐	☐	☐
Sitting and talking to someone	☐	☐	☐	☐
Sitting quietly after a lunch without alcohol	☐	☐	☐	☐
In a car, while stopped for a few minutes in traffic	☐	☐	☐	☐

63. Rate the extent to which, in recent months, fatigue has interfered with your . . .

	Not at all	-	Somewhat	-	Very much
Activity level	☐	☐	☐	☐	☐
Mood	☐	☐	☐	☐	☐
Work	☐	☐	☐	☐	☐
Home chores	☐	☐	☐	☐	☐
Relationships	☐	☐	☐	☐	☐
Enjoyment of life	☐	☐	☐	☐	☐

64. The following items relate to how tired or energetic you generally feel, irrespective of whether you have had enough sleep or have been working very hard. Some people appear to "suffer" from permanent tiredness, even on rest days and holidays, while others seem to have limitless energy. Please indicate the degree to which the following statements apply to your own normal feelings.

	Not at all	-	Somewhat	-	Very much so
I generally feel I have plenty of energy.	☐	☐	☐	☐	☐
I usually feel drained.	☐	☐	☐	☐	☐
I generally feel quite active.	☐	☐	☐	☐	☐
I feel tired most of the time.	☐	☐	☐	☐	☐
I generally feel full of vigor.	☐	☐	☐	☐	☐
I usually feel rather lethargic.	☐	☐	☐	☐	☐
I generally feel alert.	☐	☐	☐	☐	☐
I often feel exhausted.	☐	☐	☐	☐	☐
I usually feel lively.	☐	☐	☐	☐	☐
I feel weary much of the time.	☐	☐	☐	☐	☐

65. Comments

Alertness Indicators

Driving Experiences

If you sometimes drive to work, please answer the following questions. *If you don't drive to work, please skip to the Events at Work section.*

66. In the last year, how often have you had a momentary lapse of attention while you were driving to or from:

	N/A or don't know	Never	Sometimes	Frequently	Always
early shifts (i.e., shift starts before 0800)?	☐	☐	☐	☐	☐
day shifts (i.e., shift starts between 0800 & 0959)?	☐	☐	☐	☐	☐
mid-day shifts (i.e., shift starts between 1000 & 1259)?	☐	☐	☐	☐	☐
afternoon shifts (i.e., shift starts between 1300 & 1959)?	☐	☐	☐	☐	☐
midnight shifts (i.e., shift starts between 2000 & 0100)?	☐	☐	☐	☐	☐

67. In the last year, how often have you had a momentary lapse of attention while you were driving from:

	N/A or don't know	Never	Sometimes	Frequently	Always
a light shift?	☐	☐	☐	☐	☐
a busy shift?	☐	☐	☐	☐	☐
a shift giving or receiving OJT?	☐	☐	☐	☐	☐

68. In the last year, how often did you fall asleep (for a few seconds) while you were driving to or from:

	N/A or don't know	Never	Sometimes	Frequently	Always
early shifts (i.e., shift starts before 0800)?	☐	☐	☐	☐	☐
day shifts (i.e., shift starts between 0800 & 0959)?	☐	☐	☐	☐	☐
mid-day shifts (i.e., shift starts between 1000 & 1259)?	☐	☐	☐	☐	☐
afternoon shifts (i.e., shift starts between 1300 & 1959)?	☐	☐	☐	☐	☐
midnight shifts (i.e., shift starts between 2000 & 0100)?	☐	☐	☐	☐	☐

69. In the last year, how often did you fall asleep (for a few seconds) while you were driving from:

	N/A or don't know	Never	Sometimes	Frequently	Always
a light shift?	☐	☐	☐	☐	☐
a busy shift?	☐	☐	☐	☐	☐
a shift giving or receiving OJT?	☐	☐	☐	☐	☐

Events at Work

70. **Have you had any proximity events (PEs), operational deviations (ODs), or operational errors (OEs) in the last year?**

☐ Yes ☐ No

71. **If yes, do you believe that your own fatigue contributed to the PE, OD, or OE?**

☐ Yes ☐ No

72. **If you believe fatigue contributed, please indicate what you believe caused your fatigue. (Check all that apply.)**

☐ Workload ☐ Work schedule ☐ Commute ☐ Other

☐ Family ☐ Health ☐ Personal problems

If other, please describe.

73. Comments

Summing Up

Level of Fatigue

74. How often do the following occur?

	Never	Rarely	Sometimes	Frequently	Usually	N/A or Don't know
Fatigue affects my general health and well-being.	☐	☐	☐	☐	☐	☐
I experience fatigue when at work.	☐	☐	☐	☐	☐	☐
Fatigue affects my ability to perform my job effectively.	☐	☐	☐	☐	☐	☐
I see air traffic controllers who are fatigued at work.	☐	☐	☐	☐	☐	☐
Fatigue affects the ability of air traffic controllers to perform their job effectively.	☐	☐	☐	☐	☐	☐

75. To what extent do you believe that the current level of fatigue experienced by air traffic controllers as a whole, represents a safety risk?

No risk	Slight risk	Moderate risk	High risk	Extreme risk	N/A or Don't Know
☐	☐	☐	☐	☐	☐

Causes of Fatigue

76. If you experience fatigue at work, to what extent do you feel that the following contribute to your fatigue?

	Not at all	Slightly	Somewhat	Very much	Extremely
Workload/traffic	☐	☐	☐	☐	☐
Work schedule	☐	☐	☐	☐	☐
Workplace interactions	☐	☐	☐	☐	☐
Work/life balance	☐	☐	☐	☐	☐
Personal problems	☐	☐	☐	☐	☐
Workplace lighting	☐	☐	☐	☐	☐
Commute	☐	☐	☐	☐	☐
Sleep disorders	☐	☐	☐	☐	☐
Other health problems	☐	☐	☐	☐	☐
Other	☐	☐	☐	☐	☐

If other, please describe.

Reducing Fatigue

77. What, if anything, could your immediate supervisors or managers do to reduce controller fatigue?

78. What, if anything, could upper-level FAA management do to reduce controller fatigue?

79. What, if anything, could controllers do to reduce their fatigue?

80. Would you like training or information on ways to reduce fatigue?

☐ Yes ☐ No

Staying Home from Work When Fatigued

81. How often, in the last year, have you called in sick because you were fatigued?

☐ 0 times ☐ 1-2 times ☐ 3-5 times ☐ 6-10 times ☐ 10+ times

82. How often, in the last year, have you taken annual leave due to fatigue?

☐ 0 times ☐ 1-2 times ☐ 3-5 times ☐ 6-10 times ☐ 10+ times

83.

	N/A	Not at all	Not very	Somewhat	Very	Extremely
How comfortable do you feel taking time off because of fatigue?	☐	☐	☐	☐	☐	☐
How comfortable would you feel telling your supervisor that fatigue is the reason you want to take sick time or annual leave?	☐	☐	☐	☐	☐	☐
How likely is it that your supervisor would authorize annual leave to reduce fatigue?	☐	☐	☐	☐	☐	☐

Job Satisfaction

84. Please indicate the extent to which you agree or disagree with the following statements.

	Strongly disagree	Disagree	Slightly disagree	Neither agree nor disagree	Slightly agree	Agree	Strongly agree
Generally speaking, I am satisfied with my job.	☐	☐	☐	☐	☐	☐	☐
I frequently think of quitting.	☐	☐	☐	☐	☐	☐	☐

85. Please indicate your level of satisfaction or dissatisfaction with the following aspects of your job.

	Dissatisfied	Somewhat dissatisfied	Neither satisfied nor dissatisfied	Somewhat satisfied	Satisfied
Schedule	☐	☐	☐	☐	☐
Workload	☐	☐	☐	☐	☐
Type of work	☐	☐	☐	☐	☐
Relations with co-workers	☐	☐	☐	☐	☐
Relations with supervisors	☐	☐	☐	☐	☐
Work/life balance	☐	☐	☐	☐	☐
Influence on health & well-being	☐	☐	☐	☐	☐
Commute	☐	☐	☐	☐	☐
Other	☐	☐	☐	☐	☐

If other, please describe.

86. Comments

Background Information

87. Age

- ☐ 25 or under
- ☐ 26-30
- ☐ 31-35
- ☐ 36-40
- ☐ 41-45
- ☐ 46-50
- ☐ 51-55
- ☐ 56+

88. Which one of the following best describes your current position?

- ☐ Administrative Manager or support
- ☐ Operations Manager
- ☐ Front Line Manager
- ☐ CPC-Domestic
- ☐ CPC-Oceanic
- ☐ Developmental-Domestic
- ☐ Developmental-Oceanic
- ☐ Traffic Management Coordinator
- ☐ Supervisor, Traffic Management Coordinator
- ☐ Other

89. How many years have you been in your current position?

☐ less than 1 ☐ 1-4 ☐ 5-9 ☐ 10-19 ☐ 20-29 ☐ 30+

90. How many years have you been affiliated professionally with ATC (includes military)?

☐ less than 1 ☐ 1-4 ☐ 5-9 ☐ 10-19 ☐ 20-29 ☐ 30+

If other, please describe.

[ ]

91. Please indicate your current facility type.

- ☐ Tower
- ☐ TRACON/RAPCON
- ☐ Tower/TRACON/RAPCON
- ☐ En Route Center (ARTCC, CERAP)
- ☐ Command Center (ATCSCC)
- ☐ Headquarters/Regional Office or Service Area/Technical or Aeronautical Center
- ☐ Other

If other, please describe.

[ ]

92. Please indicate your facility level-

- ☐ 4
- ☐ 5
- ☐ 6
- ☐ 7
- ☐ 8
- ☐ 9
- ☐ 10
- ☐ 11
- ☐ 12
- ☐ Not known

93. Is this a 24 hour facility?

☐ Yes ☐ No

94. **If you are NOT located at Washington Headquarters, the Technical Center, the Aeronautical Center, or a regional office, please print your facility identifier. (Example: M 9 8)**

[ ][ ][ ]

95. **If you have heard that your facility is participating in the Controller Fatigue and Alertness Monitoring Study (C-FAMS), and you plan to volunteer for it, please create an easily remembered four-digit PIN, enter it in the box below, and record it for safe-keeping. If you are selected for C-FAMS, this PIN will be used to correlate (anonymously) your survey responses with your C-FAMS data. Thus, it is important that you be able to remember your PIN.**

Thank you for contributing your valuable time to complete this survey.

Appendix B. Field Study Informed Consent

Ames Research Center

CATEGORY II – HUMAN RESEARCH
MINIMAL RISK CONSENT

To the Research Participant: Please read this consent form and the attached protocol and/or subject instructions carefully. Make sure all your questions have been answered to your satisfaction before signing.

A. **I agree to participate** in the "Controller Fatigue and Alertness Monitoring Study (CFAMS) research experiment as described in the attached protocol or subject instructions. I understand that I am employed by N/A who can be contacted at ________.

B. **I understand that my participation could cause me minimal risk*, inconvenience, or discomfort.** The purpose and procedures have been explained to me and I understand the risks and discomforts as described in the attached research protocol.

C. **To my knowledge,** I have no medical conditions, including pregnancy, that will prevent my participation in this study. I understand that if my medical status should change while I am a participant in the research experiment there may be unforeseeable risks to me (or the embryo or fetus if applicable). I agree to notify the Principal Investigator (PI) or medical monitor of any known changes in my condition for safety purposes.

D. **My consent to participate has been freely given.** I may withdraw my consent, and thereby withdraw from the study at any time without penalty or loss of benefits to which I am entitled. I understand that the PI may request my withdrawal or the study may be terminated for any reason. I agree to follow procedures for orderly and safe termination.

E. **I am not releasing NASA or any other organization or person from liability for any injury** arising as a result of my participation in this study.

F. **I hereby agree that all records collected by NASA in the course of this study are available** to the research study investigators, support staff, and any duly authorized research review committee. I grant NASA permission to reproduce and publish all records, notes, or data collected from my participation, provided there will be no association of my name with the collected data and that confidentiality is maintained, unless specifically waived by me.

G. **I have had an opportunity to ask questions and have received satisfactory answers** to all my questions. I understand that the PI for the study is the person responsible for this activity and that any questions regarding the research will be addressed to him/her during the course of the study. I have read the above agreement, the attached protocol and/or subject instructions prior to signing this form and I understand the contents.

* ***Minimal Risk*** means that the probability and magnitude of harm or discomfort anticipated in the research are not greater, in and of themselves, than those ordinarily encountered in daily life or during the performance of routine physical or psychological examinations or tests.

Signature of Research Participant Date	Signature of Principal Investigator Date
Printed/Typed Name of Research Participant	Dr. Norbert Kraft Printed/Typed Name of Principal Investigator
Address	650-793-5427 Telephone Number of Principal Investigator
City, State, Zip Code	**Subject Signature:** Authorization for Videotaping
Telephone Number of Test Subject	**Subject Signature:** Authorization for Release of Information to Non-NASA Source(s)

ARC 475 (MAR 06) Previous editions are obsolete

Appendix C. C-FAM Participant Take-Home Guide

STUDY OVERVIEW

Participants are required to:

- Wear an '**actigraph' watch** that records sleep and wake periods for the full two weeks
- Keep a **sleep/activity log** for the two-week period
- Take a 5-minute **alertness test** (PVT) three times during each work shift
- Take the NASA on-line **Fatigue Factors Survey**

Actigraph Watch

- Wear 24 hours per day on your non-dominant wrist throughout the 14 days of the study
- Take off during showers, swimming, or other activities likely to damage it
- Put back on as soon as you are done with these activities
- Record the removal of the watch on the sleep/activity log

Sleep/Activity Log

- Use the **Activity Codes** to record the beginning of new activities on your sleep/activity log
- Make a **Fatigue Rating** each time you **wake up** from sleep or a nap and **before each PVT**
- Give a **Workload Rating** of your immediately prior shift segment **before 2nd & 3rd PVT** each shift

ACTIVITY Codes

Use the **Activity Codes** to record the beginning of each of these activities. After PVT Tests, put W if going back to Work or E if Ending work for the day. When putting Actigraph watch back on, put code for activity at that time (e.g., A if awake away from work, S if going to sleep).

S **– S**leep (begin sleep of any duration, including naps)
A **– A**waken (from sleep of any duration, when not at work)
W – Start or Resume **W**ork
E – **E**nd Work
T – PVT **T**est
O – Actiwatch **O**ff (e.g., shower, swimming)

FATIGUE Ratings

Complete each time you **wake up** from sleep or a nap and **before each PVT**.

1 - Feel active and vital; alert; wide awake
2 - Functioning at a high level, but not at peak; able to concentrate
3 - Relaxed; awake; not at full alertness; responsive
4 - A little foggy; not at peak; let down
5 - Fogginess; beginning to lose interest in remaining awake; slowed down
6 - Sleepiness; prefer to be lying down; fighting sleep; woozy
7 - Almost in reverie; sleep onset soon; lost struggle to remain awake

WORKLOAD Ratings

Rate your workload during your immediately prior shift segment **before 2nd & 3rd PVT** each shift

1-----2-----3-----4-----5-----6-----7
Very Average Very
Low High

Example of a Completed Sleep/Activity Log for One 24-Hour Period

DAY 1	0000		0100		0200		0300		0400		0500		0600		0700		0800		0900		1000		1100	
Activity	S																A	O						
Fatigue																	2							
Workload																								

DAY 1	1200		1300		1400		1500		1600		1700		1800		1900		2000		2100		2200		2300	
Activity			T								T								T	E			O	S
Fatigue			2								4								3					
Workload											4								3					

Psychomotor Vigilance Task (PVT) Alertness Measure

- Take on Palm Centro with your **ID code on the back** three times during each work shift
- Take first PVT at the **beginning** of each work shift
- Take second PVT as close to the **middle** of each shift as possible
- Take third PVT **after your final break** of each work shift

PVT Instructions:

1. **Press the red power button** (largest button on the right) to turn on the device. Then **press the Palm logo button** (in the middle of the device) to unlock the keys. The top of the screen should read Psychomotor Vigilance Test.
2. **Press the Down button** (below the Palm logo) to scroll down and **highlight your participant ID number**. Do **NOT** press the Up button if you pass your ID number, as this will begin the test. Instead continue pressing the Down button until you come to your ID number again.
3. **Press the Up button** (above the palm logo) **to begin the test**.
4. During the test you will watch the screen. **As soon as a target appears, press the response button with the thumb of your dominant hand**. (Hold the Palm in your non-dominant hand.)
   If your **dominant** hand is your **right hand, push the 'HOME' button** (drawing of a house).
   If your **dominant** hand is your **left hand, push the 'PHONE' button** (drawing of a phone).
   When you press the button your response time (in hundredths of a second) will be displayed.
   Do not press any other buttons.
   Try to be as fast as possible, but do NOT press the button before the target appears. The test will take 5 minutes.
5. When the test is complete the data will automatically be saved and the device will turn off.
6. Plug the device back into the power cord to keep it fully charged.

If you accidentally begin a test with the incorrect ID number:

- **Press the 'V' key** to interrupt and cancel the test.
- When the "Save this session?" dialog appears, select '**NO**' to cancel the test without saving data.
- If for any reason you are unable to cancel a test taken with the wrong ID number, please call the NASA researchers at 650-793-5427 right away, 24/7, and leave a message if there is no answer.

If the system freezes and you need to interrupt a test (either the target does not appear for more than a minute, or it will not disappear), **please press the 'V' key and start over**. If the freeze was caused by a **low battery** (as indicated by a flashing red light), it may be necessary to complete your test while the device is attached to a charger.

Fatigue Survey

Please take the C-FAM survey at http://nasasurvey.us during duty hours during the 14-day data collection period. Please enter your ID code, e.g. ZNY12, in the box at the end of the survey.

If the above site is blocked by your firewall, please try https://secure.inquisiteasp.com/surveys/XWHZ58/

Appendix D. Actiwatch Sleep Parameters

Sleep Parameter	Detailed Explanation
Bed Time	Time when lights are switched off. This is set by the operator or set automatically by the analysis software reading an event marker.
Get Up Time	Time when lights are switched on. This is set by the operator or set automatically by the analysis software by reading an event marker.
Time in Bed	The difference between the Get Up and Bed times.
Sleep Start / Sleep Onset	The start of sleep as set by the operator or determined automatically by the sleep algorithm. The first minute that the analysis software scores “asleep”.
Sleep End	The end of sleep as set by the operator or determined automatically by the sleep algorithm.
Assumed Sleep	The difference between sleep end and sleep start.
Actual Sleep Time/ Total Sleep Time (TST)	The amount of sleep as determined by the algorithm and is equivalent to assumed sleep minus wake time. The total number of minutes scored as “asleep”.
Actual Awake Time / Wake after Sleep Onset (WASO)	The amount of time spent awake as determined by the algorithm. The total number of minutes the subject was awake after sleep onset occurred.
Actual Sleep and Wake Time %	These are displayed to the right of the Actual Sleep and Actual Wake boxes.
Sleep Efficiency	The Actual Sleep Time divided by Time in Bed. Defined as the proportion of sleep in the episode potentially filled by sleep (i.e., the ratio of total sleep time to time in bed). Normal sleep efficiency is at least 85%. It is reduced in a number of situations, such as insomnia or lab effect.
Sleep Latency	The latency before sleep onset following bed time.
Number of Sleep Bouts	The actual number of episodes of sleep.
Number of Wake Bouts/ Awakenings	The actual number of episodes of wakefulness. The number of different awakening episodes as scored by the algorithm. This is sometimes referred to as Frequency of Awakenings (shown as the number of awakenings per night).
Mean Length of Sleep and Wake Bouts	These figures are determined by dividing the total duration of sleep and wake by the corresponding number of sleep and wake bouts.
Number of Minutes Immobile	The total number of minutes during the assumed sleep period where the counts per minute are below a predetermined “immobility” threshold.
Number of Minutes Moving	The converse of the above being the total number of minutes where scores greater than the “immobility” threshold were recorded during the assumed sleep period.
Percentage of Minutes Immobile	The Number of Minutes Immobile divided by the Assumed Sleep period.
Percentage Minutes Moving	The Number of Minutes Moving divided by the Assumed Sleep period.
The Number of Immobile Phases	The number of periods of continuous periods made up of consecutive epochs where the counts are less than the “immobility” threshold.
The Number of Immobile Phases of 1 Minute	The number of immobile phases where the duration is no more than 1 minute.

Sleep Parameter	Detailed Explanation
Percentage Immobility	The Number of Immobile Phases of 1 Minute as a proportion of the Number of Immobile Phases.
Fragmentation Index	The addition of Percentage Minutes Moving and Percentage Immobility. This is used as an indicator of restlessness.
Average Awakening	The average length in minutes of all awakening episodes.
Total Counts	The total actigraphy counts summed together for the entire sleep period.

Appendix E. C-FAM Field Study Web Signup Page

NASA ATC Fatigue Research
Survey & Field Study

Ames Research Center

NASA is studying Air Traffic Controller fatigue to help NATCA and the FAA understand fatigue in the ATC work force.

Take the NASA ATC Fatigue Factors Survey--open until December 31

CLICK HERE to take the Survey

- The survey is meant for all controllers and managers
- If you have any questions about the NASA Survey, please contact:
  - Bonny Parke, Ph.D., (650) 604-2716
    bonny.parke@nasa.gov

Sign Up for the NASA ATC Field Study

CLICK HERE to sign up for the Field Study

- The study is meant for controllers from the following facililties:

  April - July
  - ZAU, ZNY, JFK, ZDC, BWI, IAD, PCT, PHL, N90, EWR, LGA, C90, ORD

  August - December
  - SCT, DEN, ZDV, D01, SLC, ZOA, LAS, L30, SFO, OAK, SEA, PDX, PHX, IAH,
  - DFW, I90, NCT, D10

- If you have any questions about the NASA Field Study (C-FAM), please contact:
  - Norbert Kraft, M. D. (650) 793-5427
    ARC-Research-Team@nasa.gov