# Assessing Fatigue Risk in FAA Air Traffic Operations

Report by
Scientific Expert Panel on Air Traffic Controller
Safety, Work Hours, and Health

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# Introduction

The FAA's air traffic controller workforce has a central role in the safe and efficient movement of people and aircraft in the National Airspace System (NAS). Daily, 45,000 flights carry 2.9 million passengers to their destinations, guided by more than 13,000 air traffic controllers operating in 313 facilities.[1] Around-the-clock, every day, these air traffic controllers confront known challenges to humans working in 24/7 operational settings, amplified even further in safety-sensitive environments where errors can mean lives lost and people injured. Fatigue related to sleep loss and circadian disruption is created when human operators work schedules around-the-clock and is known to have significant adverse effects across safety, performance, health, and mood. For this reason, the FAA Administrator requested that: "a small group of independent, objective experts evaluate the latest science on human sleep needs and fatigue considerations as applied to FAA's current air traffic controller workforce, work requirements, and scheduling practices. The purpose of this evaluation is to inform FAA's ongoing efforts to enhance the safety and well-being of the agency's controller workforce and the safety of the aviation system."

To meet this request, a small team of scientific experts on sleep, circadian, and fatigue factors in operational settings, undertook a focused, short-term evaluation of the three specific areas identified by the FAA Administrator: air traffic controller 1) workforce, 2) work requirements, and 3) scheduling practices. The FAA provided two air traffic subject matter experts to offer technical support and access to relevant individuals, reports, and data. Given the extensive amount of information provided to the Scientific Expert Panel on Air Traffic Controller Safety, Work Hours, and Health, the original six-week timeframe was extended to ten weeks. This timeframe is highlighted to explicitly emphasize that this effort was a focused, intensive examination of the areas identified, intended specifically to identify the strengths, risks, and opportunities related to fatigue risks in air traffic operations. It was operationally focused and not a research project that would stretch over many months or years. By identifying the strengths, risks, and opportunities related to fatigue risks in air traffic operations, this evaluation is intended to provide a guide and tool for FAA actions to "enhance the safety and well-being of the agency's controller workforce and the safety of the aviation system."

Over the course of this project, 120 documents were provided, about 25 meetings/interviews were held with internal FAA and external individuals, four air traffic operations (ATO) facilities were visited, and data from 700,000 individual work hours and days off from more than 10,000 controllers during January 2024 were analyzed. There were many individuals who provided an extensive amount of information for this project, and who are acknowledged in Appendix B. These included individuals with the FAA, the National Air Traffic Controllers Association (NATCA), the National Transportation Safety Board (NTSB), and many others, as well as Guidehouse, who provided valuable support throughout the project. Information about the Scientific Expert Panel on Air Traffic Controller Safety, Work Hours, and Health is in Appendix C. Other appendices provide an overview of relevant sleep, circadian, and fatigue factors, a glossary of terms, references, and other relevant information.

The International Civil Aviation Organization (ICAO) defines fatigue as: "A physiological state of reduced mental or physical performance capability resulting from sleep loss, extended wakefulness, circadian phase, and/or workload (mental and/or physical activity) that can impair a person's alertness and ability to perform safety-related operational duties."[2] ICAO has developed a large set of works to address fatigue risk management issues in aviation operations, including aircrew, general aviation, helicopter operators, and air navigation services.[3] There also is a significant scientific literature on sleep, circadian, and fatigue factors, including applications in diverse operational settings. These include aviation and transportation more broadly.[4] Some introductory information about relevant sleep, circadian, and fatigue factors is provided in Appendix D. This particular sleep, circadian, and fatigue information is to provide context for the scientific basis and perspective used throughout this evaluation. *The report conclusions include one specific recommendation, urges quickly initiating action on four priority opportunities, identifies the next eleven near-term opportunities, and outlines the subsequent opportunities to address the fatigue risks determined in this report.*

In the report conclusions, the Scientific Expert Panel on Air Traffic Controller Safety, Work Hours, and Health strongly recommends that the FAA form a working group to evaluate and determine next steps. The Scientific Expert Panel also strongly urges the FAA to quickly initiate action on the following four opportunities:

Integrate prescriptive policies/regulations and Fatigue Risk Management System (FRMS) into an appropriately structured single system that provides one source for FAA ATO Fatigue Risk Management (FRM) activities that includes a single source repository of all relevant materials, ensuring consistency across elements, and emphasizing the integrated and complementary elements of the system. (Opportunity: *PPR/FRMO1)*

Identify and determine specific circumstances around a subset of representative scheduling policy and agreement exceedances then implement mechanisms to monitor and eliminate such exceedances. This effort should be focused on developing and implementing these mechanisms and not involve punitive actions for past circumstances. (Opportunity: *BNO2*)

Develop and implement a strategy to eliminate the counterclockwise rotating 2-2-1 schedule and replace it with a schedule design that meets operational requirements and that incorporates sleep and circadian principles. (Opportunity: *BNO3*)

Develop and implement a strategy to update the current prescriptive policies to address identified fatigue factors, especially to avoid known schedule practices that induce fatigue. Specifically, require sufficient time off-duty (e.g., 10-12 hours) before all shifts, whether controllers are performing operational or non-operational tasks. Also, this off-duty time should account for the circadian timing of the shift, where increased off-duty time may be required before midnight shifts. (Opportunity: *BNO4*)

Beyond these initial four priority actions, the Scientific Expert Panel identified the next eleven opportunities for near-term attention, and another 43 opportunities for ongoing efforts to address the fatigue risks examined. There are a total of 58 opportunities identified throughout this report that offer specific actions to reduce or mitigate fatigue risks in controller operations.

The Scientific Expert Panel on Air Traffic Controller Safety, Work Hours, and Health determined that examining the strengths, risks, and opportunities regarding fatigue in the air traffic controller workforce, work requirements, and scheduling practices would provide the most effective guide and tool for FAA future actions. This provides a framework to enhance strengths and address fatigue risks to minimize or eliminate them. By identifying opportunities to enhance strengths and address fatigue risks, the FAA, and relevant stakeholders such as NATCA, can establish appropriate working groups, identify near- and long-term objectives and activities, and pursue actions informed by their expertise and the realities of everyday operational demands, staffing, and funding. Hence, the Scientific Expert Panel on Air Traffic Controller Safety, Work Hours, and Health identified a large, broad set of opportunities for the FAA and others to consider and pursue in their efforts to "enhance the safety and well-being of the agency's controller workforce and the safety of the aviation system."

[1] Federal Aviation Administration. (2023). Air Traffic by the Numbers. https://www.faa.gov/air_traffic/by_the_numbers

[2] International Civil Aviation Organization. (2015). *Fatigue Management Guide for Airline Operators (2nd ed.)*. https://www.icao.int/safety/fatiguemanagement/FRMS%20Tools/FMG%20for%20Airline%20Operators%202nd%20Ed%20(Final)%20EN.pdf

[3] International Civil Aviation Organization. (n.d.). *Resources*. https://www.icao.int/safety/fatiguemanagement/pages/resources.aspx

[4] Rudin-Brown, C. M., & Filtness, A. J. (2023). *The Handbook of Fatigue Management in Transportation*. CRC Press. https://doi.org/10.1201/9781003213154

# Section I: Workforce

Workforce fatigue risk factors were examined for current strengths, risks, and opportunities to enhance strengths and address risks. Four workforce areas were evaluated: staffing, prescriptive policies/regulations and fatigue risk management (FRM), health, and other factors.

## Section I(a): Staffing

### *Strengths*

The FAA is responsible for operating the NAS with authorities over safety, operations, regulation, training, licensing, certification, enforcement, economics/budgets, and much more. The FAA's integrated authority and oversight for the NAS is a strength in providing a safe and effective air transportation system. The FAA responsibilities include air traffic operations and the many diverse, associated components required to provide a safe NAS. Air traffic controllers (ATC) are a central asset to operating the NAS and ensuring the round-the-clock safety of the system.

Covering the work requirements for a 24-hours per day, 7-days per week, and 365-days per year operation is a complex and dynamic challenge. In a safety-critical operational environment like air traffic operations (ATO), the potential costs of errors, near misses, and incidents/crashes establish a very high bar and expectations for safety. Hence, the critical need to ensure the optimal safety and performance of the NAS through a core element: the controllers performing diverse tasks around-the-clock. These tasks vary by many factors, including facility requirements, traffic type and flow, and geography and are conducted by Certified Professional Controllers (CPCs), Certified Professional Controllers in Training (CPC-ITs), Developmental Controllers, and ATC Academy students. In Fiscal Year (FY) 2023 Pay Period Six, there were a total of 13,367 individuals working in these positions across 313 facilities. Along with many other elements (procedures, training, technology, etc.), these controllers are part of a remarkably safe system that allows the current high-performance and effectiveness of the NAS. These professional controllers are clearly a strength of the current system.

The FAA's *Air Traffic Controller Workforce Plan 2023-2032* is an annual report that examines the workforce needs across a decade with details and specifics for meeting ATO safety and operational requirements of the NAS. Specifically, regarding workload and traffic, the Plan indicates the following: "An important part of managing the NAS involves actively aligning controller resources with demand. The FAA 'staffs to traffic,' matching the number of air traffic controllers at its facilities with traffic volume and workload. The FAA's staffing needs are dynamic due to the dynamic nature of the workload and traffic volume." The Plan then reviews headcount, retirements, hiring, training, future staffing targets, and provides plans for meeting the air traffic operations workforce needs.[1] This annual report, examining issues over a 10-year period, clearly acknowledges the complex challenges that must be addressed to ensure a sufficient, well-trained controller workforce. It has an historical perspective supporting future needs and plans and gives visibility to the challenges, requirements, and specifics to maintain NAS safety and operations related to ATO.

In the recent *2023 National Airspace System, Safety Review Team Report: Discussion and Recommendations to Address Risk in the National Airspace System*, there was a specific examination of current air traffic operations staffing. This Safety Review Team (SRT) Report, requested by the FAA Administrator, identified a variety of issues that contribute to current staffing shortages including "inadequate air traffic controller and technical operations staffing models and significant budget constraints." The Report specifically identifies the need for "a predictable, repeatable, and defensible air traffic controller staffing model" acknowledging that it "is critical to achieving a sustainable level of staffing as well as efficient and effective training."[2] The Report also reviews the current disagreement among ATO stakeholders on a facility-level staffing model, though there have been efforts to address this situation with survey instruments and using MITRE as an independent expert for model validation efforts of the Collaborative Resources Workgroup (CRWG).

The SRT provided 12 recommendations related to staffing that addressed a range of identified issues such as "develop a defensible, flexible, predictive [ATC] staffing model that determines system and individual facility needs", "acquire and implement state-of-the-art training systems", and "develop a tool to assist facility schedulers in automatically identifying outstanding required training prior to their placement on the schedule."[2] *The report also emphasizes the critical need to address funding for this issue.*

The FAA Workforce Plan and the recent NAS SRT report are just two examples of the focus on the controller workforce and staffing requirements specifically. There is a long history and numerous efforts to address these staffing challenges. For example, there is a 1997 Transportation Research Board (TRB), National Research Council of the National Academies report (report 250) on improving methods for determining staffing requirements,[3] a 2014 TRB, National Research Council of the National Academies report (report 314) on the FAA's Approach for Determining Future Air Traffic Controller Staffing Needs,[4] and the most recent 2023 CRWG CPC Targets (Executive Summary)[5] cited in the SRT Report.[2]

Clearly, these numerous efforts over almost two decades show that determining the actual number of controllers required to maintain safe, effective operations around-the-clock is a very complex and dynamic challenge with diverse variables. The focus of this current report is on one of those variables: sleep, circadian, and fatigue risks, which have their own level of dynamic complexity.

These examples acknowledge the significant disparity between staffing needs and actual levels in the current system and at individual facilities, provide visibility to the necessities and challenges to meeting these needs, and outline plans and actions to address them. The acknowledgment, visibility, plans, specifics, data, recommendations and much more put the FAA and ATO stakeholders in a strong position to meet staffing objectives *if* effective actions are taken. Clearly, enacting the diverse recommendations and plans involves many factors and complex issues and systems that will require near- and long-term actions to meet staffing objectives. There is no one solution that will immediately relieve the discrepancy between staffing requirements and actual, current levels.

Acknowledging this situation, the FAA is already implementing actions to address these staffing needs. For example, the FAA announced five immediate actions in response to the SRT Report.[6]

### *Risks*

An absolute requirement for safe and effective air traffic operations is to have a sufficient number of personnel to meet system and facility needs. In the absence of enough individuals to perform the required tasks/workload, the current system employs a variety of strategies to maintain the expected operational tempo at the expected safety level. For example, overtime (mandatory or voluntary), extended consecutive work days, forgoing training, combining positions (e.g., requiring a controller to manage a larger operational area), and utilizing supervisors to manage operational duties are indicators that insufficient staffing is available to manage system requirements. These examples all represent fatigue risks with increased risk severity as various elements are extended (e.g., work hours, consecutive work days, overtime, shift rotations). While increased traffic flow, sick leave, weather, and emergencies can create acute, short-term demands, extended use of these approaches can increase fatigue risks that will accumulate over time.

A data-based, validated staffing model for air traffic operations is a fundamental requirement to address fatigue risks. Then enacting the model is critical to address both near- and long-term staffing needs to provide the actual controller resources required for safe and effective operations. The longer it takes to definitively address this staffing discrepancy, the longer staff-related fatigue risks will exist in the system and be compounded over time. *Also, without sufficient staffing, some of the opportunities identified in this report may be unattainable, delayed, or constrained. Even when at optimal staffing levels, there will be continued fatigue risks related to known sleep and circadian disruptions created by around-the-clock shiftwork demands.*

Clearly, the other two areas examined in this report directly affect workforce staffing: work requirements and scheduling practices. Specifically, work requirements address a basic factor in determining workforce staffing needs by estimating how much work an individual can perform and how long they can maintain safe and effective performance. Scheduling practices will determine when and how those individual controllers will be available to perform the required work.

Staffing levels also affect schedule stability and predictability as well as overtime and extended work (per day, week, months). Schedule consistency contributes to effective fatigue management as does predictability. Weather, sick leave, and unexpected events can significantly disrupt both the stability and predictability of work schedules with direct effects on sleep and circadian patterns. Maintaining operational flexibility is critical to managing these disruptions while balancing the fatigue challenges of potential sleep and circadian disruptions. Cumulative fatigue effects due to overtime and extended work periods also will increase safety risks.

There is foundational work that provides quantified information on the actual tasks that controllers perform.[7-11] This task information is a basic, critical building block to determining workload. A task analysis is “the study of what an operator (or team of operators) is required to do, in terms of actions and/or cognitive processes, to achieve a system goal.” This acknowledges that tasks may involve cognitive elements and/or physical actions. Task analyses can be used for a variety of objectives such as safety, productivity/efficiency, staffing, skills and knowledge acquisition, performance assurance, and system evaluation.[12] Conducting task analyses provides a method to quantify controllers' tasks performed across different positions/jobs. These data are then used for determining actual workload more specifically and realistically portray job requirements in workload staffing models. It would be useful to review and refine the available task analysis data to identify where updated or more thorough analyses are needed. A refined task analysis will also ensure that current usage in workload models aligns with the sleep, circadian, and fatigue risk issues and opportunities identified in this report.

Also, when the word "workload" is used in discussions of staffing, it typically portrays a generalized view and often the actual workload is neither quantified or specified. For example, the FAA describes: "A primary factor affecting controller workload is the demand created by air traffic operations" and "Adequate numbers of controllers must be available to cover the peaks in traffic caused by weather and daily, weekly or seasonal variations, so we continue to 'staff to traffic.' Although the FAA generally staffs to traffic counts, it is not a one-to-one relationship." Using task analyses data to build data-based workload models provides a method to quantify workload staffing requirements, explore potential changes, and evaluate overall system outcomes. Like with task analysis, it would be useful to review and refine the available workload data to identify where updated or more thorough analyses are needed. A refined task analysis will also ensure that current usage of workload models aligns with the sleep, circadian, and fatigue risk issues and opportunities identified in this report.

While there is a long history of task analysis and workload research examining air traffic operations, findings from these activities become outdated quickly due to changing technology and air traffic. Additionally, task analyses need to be considered in the context of sleep, circadian, and fatigue risks. A review of this literature can identify gaps in knowledge and especially operational applications that would be improved when incorporating sleep, circadian, and fatigue science (e.g., time-of-day considerations). Sometimes, the translation of relevant findings from operational research into actual operations can be missed or delayed. It also will be important to specifically examine task analysis and workload findings that can inform and advance staffing models with more refined calculations. This will be particularly relevant as new technologies are introduced (e.g., Next Generation Air Transportation System (NextGen)) and specific tasks and workload evolve. New technologies may be intended to enhance safety, efficiencies or reduce workload but also will introduce different risks such as monitoring complacency or cognitive load that will be affected by sleep, circadian, and fatigue factors. Many of these new technology efforts are in progress as the FAA works on future programs, such as NAS 2040 and automation opportunities in air traffic control operations.

As regards workload in the context of fatigue risks, either high or low workload levels can create risks. High workload can increase the potential for performance decrements to emerge due to multiple task requirements, time pressure, and safety considerations. Low workload situations may create the opportunity for boredom and complacency effects to emerge due to underlying fatigue factors (e.g., sleep loss or circadian disruption).

*Staffing Opportunities (SO)*
*SO1.* Establish a unified, data-based model for air traffic staffing requirements then enact changes with clear near- and long-term activities, milestones, annual evaluation, and adjustments as needed. Reflect SRT recommendations regarding staffing and funding.

*SO2.* Review available ATC task analysis and workload data to determine the current state of knowledge and gaps specifically as related to sleep, circadian, and fatigue factors, then update staffing models, including new research findings. Conduct regular reviews to maintain currency of data to reflect ATC operational tasks, demands, workload, and fatigue risks especially in the context of evolving technologies.

*SO3.* Continue, and where appropriate extend, data collection on overtime (mandatory and voluntary), extended consecutive work periods (days, weeks, months), combining positions, and supervisory roles (oversight vs. operational) then ensure findings are reflected in staffing requirements and scheduling practices to minimize fatigue risks.

*SO4.* Analyze work requirements and scheduling practices opportunities identified in this report to determine potential changes that will affect staffing needs at the system and individual facility level. Integrate identified changes into staffing models, develop a deployment strategy, and ensure plans account for near- and long-term actions.

## Section I(b): Prescriptive Policies/Regulations and Fatigue Risk Management

*Strengths*
Currently, the FAA uses a combination of prescriptive policies/regulations and fatigue risk management to address the fatigue challenges in air traffic operations. Prescriptive policies and regulations are historically used to establish boundaries to manage factors that are known to cause fatigue, such as work hours, sleep, and circadian factors. For example, these boundaries are used to limit work hours, provide sufficient sleep opportunities, limit consecutive days worked, manage circadian disruption, and provide sufficient recovery time. The Federal Aviation Regulations (FARs) that deal with pilot flight and duty times for commercial passenger operations are an example of regulations intended to manage fatigue through a prescriptive approach (e.g., 14 Code of Federal Regulations (CFR) Part 117). Similar regulations exist for flight attendants (e.g., 14 CFR Part 121.467). Example non-regulatory policy documents for pilot duty and rest scheduling have focused on commercial (NASA TM 110404, 1996) as well as business aviation operations (Flight Safety Digest, 1997; updated in 2014).[13] [14] These policy documents highlight that the biological factors that engender fatigue in all humans (e.g., sleep loss and circadian disruption) have not changed over time, while operations have evolved with increased demands, new technology, updated training, new aircraft, etc. While acknowledging the obvious operational differences, these regulatory and policy mechanisms may be useful models to inform FAA efforts to reduce and mitigate air traffic controller fatigue risks.

Duty and rest scheduling considerations for air traffic control operations are addressed through regulatory mechanisms, a collective bargaining agreement (CBA), and memorandum of understanding (MOUs). For example, regulations address maximum work hours (14 CFR Part 65.47) while a CBA between the FAA and NATCA addresses a broader range of issues and in greater detail (2016). Further arrangements can be made at individual facilities to address specific issues that may include the use of schedule variations. The CBA is the primary source for managing air traffic controller duty and rest scheduling with added flexibility through facility-specific agreements. Figure W-1 provides a summary overview of these different mechanisms.

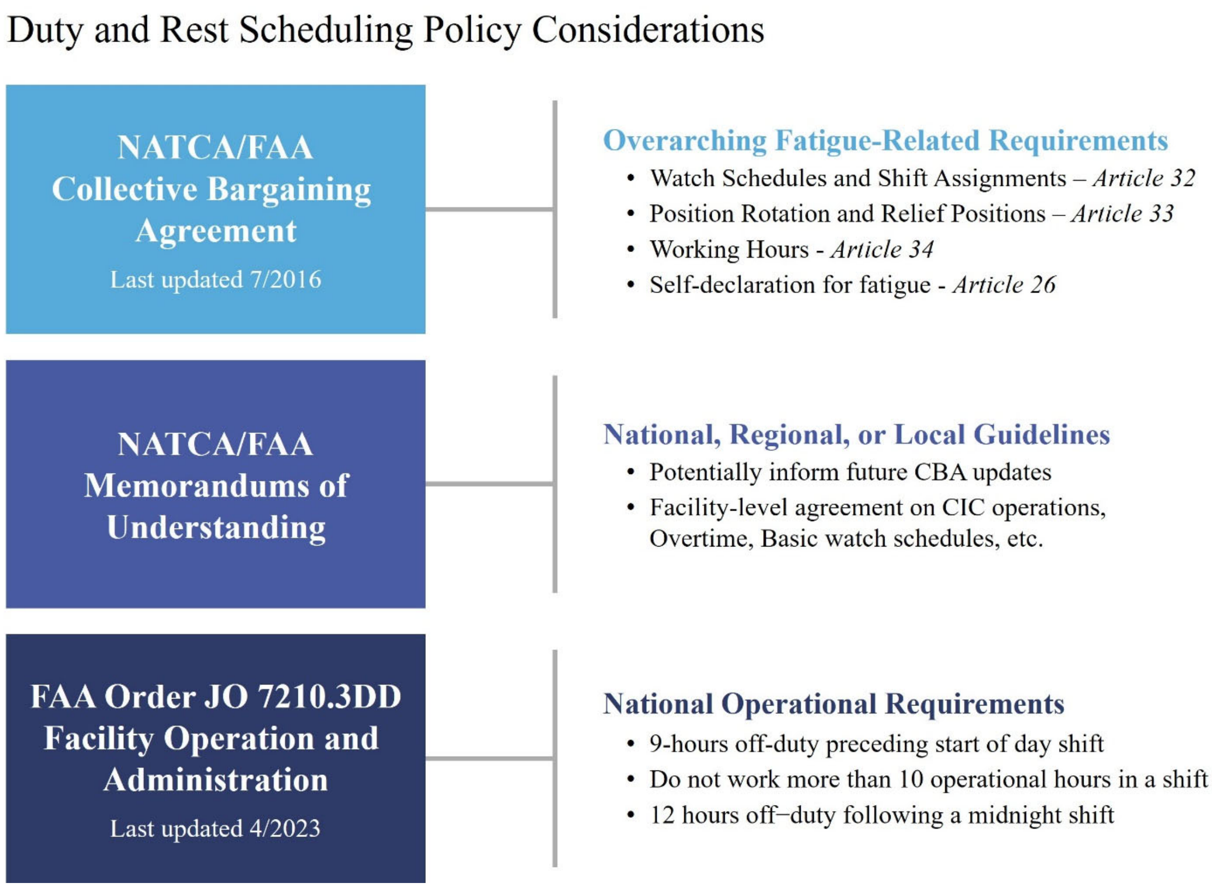


*Figure W- 1*

For over 30 years, the FAA has been conducting fatigue research using the expertise and resources at its Civil Aeromedical Institute (CAMI) in Oklahoma City to inform their fatigue management activities. Over the years, CAMI fatigue research has examined a broad range of issues related to pilots, controllers, flight attendants, and maintainers. A summary overview of this fatigue work that covers 1990 – 2022 is portrayed in Appendix F, Figures A-1 – A-4. For example, regarding controllers, in 1995 and 1996, CAMI examined the sleep/wake cycle and laboratory performance measures of the 2-2-1 shift schedule (the “rattler”).[12] [15] CAMI also has conducted air traffic controller fatigue research on the effects of clockwise and counterclockwise rotating shifts,[16] sleep patterns as a function of time off between rapidly rotating shifts,[17] [18] commuting risks factors,[19] and effects of 8- vs. 10-hour work schedules on performance and alertness.[20] Almost 25 years ago, CAMI conducted a study of napping on night shift performance.[21]

CAMI also conducted a large, Congressionally-mandated, survey of controller shift work and fatigue. The top-line results of that research study are included in Appendix E. Additional logistic regression analyses derived from these survey data and summary data from open-ended responses can be found in an earlier 2001 report from the Human Resources Research Organization.[22] Between 1990 – 2006 there are at least 23 CAMI research publications specifically related to air traffic controller fatigue research (Appendix G). These studies have examined specific operational issues, responded to Congressional tasking, and added to the scientific literature on fatigue in operational settings. Over the years, CAMI scientists have collaborated with a variety of relevant stakeholders in the aviation community to conduct their research, including operational, regulatory, safety, and research groups. The CAMI research findings can provide guidance for prescriptive policies and regulations as well as fatigue risk management activities.

As the demand for 24/7 operational activities increased, research provided a more thorough understanding of the physiological challenges to human operators in these settings, and fatigue-related incidents and crashes continued to occur, it became clear that prescriptive policies and regulations were necessary but not sufficient to manage fatigue. While prescriptive policies and regulations put boundaries on some factors that created fatigue, the complexity of diverse operational demands and human physiology required expanded strategies and tactics to more effectively manage fatigue in operational settings such as transportation. Hence the development and implementation of FRM activities that are more focused on a performance-based approach to complement historical prescriptive policies and regulations.

The FAA has been at the forefront of combining prescriptive policies and regulations with FRM approaches for pilots, including a Fatigue Risk Management Plan (FRMP) and a Fatigue Risk Management System (FRMS), as well as an FRMP for flight attendants. In 2010, the FAA published Information for Operators (InFO) (InFO 10013, 10017) regarding a requirement for 121 carriers to establish an FRMP that included nine elements. Subsequently, when new flight, duty, and rest regulations were established with 14 CFR Part 117, an FRMS was created (14 CFR Part 117.7) with details elaborated in an Advisory Circular (AC) (AC 120-103). The FRMS is an optional approach that provides a certificate-holder an alternate means of compliance to further tailor fatigue risk management activities to their operations. In 2011, the FAA also applied the FRM approach to ATC operations through Job Order (JO) 1030.7A. This order established a Fatigue Risk Management Team (FRMT) and defined the elements and functions of the ATO FRMS. The Fatigue Safety Steering Committee (FSSC) was formed and "provides an ongoing interface between ATO Safety and Technical Training and affected labor unions concerning fatigue hazards and risks across the NAS."

Currently, the are 1.5 full-time equivalents (FTE) with primary air traffic operations FRMS responsibilities who interact with the FRMT, FSSC, and others as needed. Activities are conducted under the four Safety Management System (SMS) pillars: policy and documentation, risk management, safety assurance, and safety promotion. There are at least 30 air traffic operations FRMS activities in progress or planned for 2024. For example, these include updating JO 1030.7A, exploring local (facility) schedule negotiations, several Air Traffic Safety Action Program (ATSAP) efforts, exploring creative scheduling practices, continuation of ongoing international collaborations, multiple educational course development activities, and diverse presentations. There are at least 31 distinct educational materials that are in progress or planned for 2024 that will be used across a variety of settings.

### *Risks*

Over the past 30 years, there have been many fatigue-related activities conducted by the FAA and there are many underway or planned. However, it is unclear what outcomes these efforts have provided. Have the prescriptive policies/regulations been effective? Have the FRMS activities been effective? Is there effective integration of these complementary approaches to fatigue risk management? The clear objective for all of these elements and activities is to reduce or mitigate fatigue risk in air traffic controller operations. Do they meet this objective?

There are multiple prescriptive elements that address fatigue: regulation, CBA, MOUs. The most effective prescriptive policies and regulations should be operationally relevant and science-based, sometimes a difficult balance to attain. With multiple elements, it is important that they are integrated into a complementary and clear system. If elements are in conflict, then confusion or challenges with applications may eliminate or reduce their use or effectiveness. The current system provides flexibility by using different approaches, *though it is unclear whether balance between these elements is achieved within the current system (i.e., regulation, CBA or MOUs).* Negotiated elements will be most effective in managing fatigue risk when operationally relevant and reflecting the known science related to sleep, circadian, and fatigue factors. Negotiated agreements that address safety may be affected by a broad range of competing interests such as operational demand, family considerations, commuting issues, etc. The most basic question is whether these multiple elements, and the issues addressed, effectively reduce or mitigate fatigue risks in air traffic operations. It is unclear whether there have been any evaluations conducted to determine the overall effectiveness of the current mechanisms or individual elements.

CAMI is an FAA resource intended to support the agency's mission. CAMI has conducted a significant amount of research over the past 30 years that includes extensive work related to fatigue in air traffic control operations. Much of this work has been reactive, addressing a particular fatigue issue relevant to the FAA or tasked by Congress. The CAMI research will provide the most value when it is translated into some form of application. There are diverse opportunities to use the CAMI findings, though it is unclear whether these opportunities have been optimally pursued. While CAMI work stands on its own as a valuable contribution, greater value will be attained through more expansive application of the research findings. This value may be enhanced further by evaluating the balance of reactive vs. proactive projects in the CAMI research portfolio. For example, determining new or alternate operationally relevant schedule approaches that minimize the fatigue risks of 24/7 operations or as new technologies (e.g., NextGen, NAS 2040) come online, what studies could examine fatigue issues and solutions before full implementation? Findings could potentially inform training, schedules, breaks, procedures, etc.

Acknowledging that prescriptive policies and regulations are necessary but not sufficient to manage the fatigue risks associated with air traffic operations, the FAA has developed and enacted an FRMS for 13 years. One component of an SMS and FRMS process is evaluation. This is critical to understanding which activities are effective, which are not, and how efforts can be improved. While the FAA FRMS has delivered many diverse activities and products over the years, it is unclear what outcomes they have generated and their effectiveness. For example, just counting educational materials delivered does not determine if they were actually read or used, how effective were the materials (did individuals learn the intended information?), were the individuals required to demonstrate proficiency through objective testing, did people apply the information in their job or personal life, how can the materials be improved, and much more. It is critical that the educational materials are science-based and include relevant citations and are reviewed by subject matter experts to ensure their accuracy. This is just one example. This approach of evaluating actual activity effectiveness should be applied to all FRMS elements. The objective of FRMS efforts is to obtain effective outcomes that minimize or mitigate fatigue risks. Understanding the specific intended outcome before undertaking activities is critical to ensuring that activities actually deliver the expected result.

While the ATO FRMS does track activities to SMS pillars, greater specificity is needed regarding the strategy that it is pursuing with its varied activities. Beyond listing and counting activities, it is important to establish an integrated strategy with specific measurable objectives that can be evaluated for effectiveness.

The FAA has a clearly established fatigue risk management approach that includes prescriptive policies and regulations in combination with an FRMS. Though evaluation is a core component of SMS and FRMS, there appears to be minimal explicit examinations of the individual fatigue risk management elements or the integrated system to determine if intended objectives are being attained.

*Prescriptive Policies/Regulations and Fatigue Risk Management Opportunities (PPR/FRMO)*
*PPR/FRMO1. Integrate prescriptive policies/regulations and FRMS into an appropriately structured single system that provides one source for FAA ATO FRM activities. This should include a single source repository of all relevant materials, ensuring consistency across elements, and emphasizing the integrated and complementary elements of the system. (Priority Opportunity)*

*PPR/FRMO2.* Review/evaluate each specific element of fatigue-related policies, regulations, CBA, and MOUs to determine if they meet explicit FAA FRM objectives, including their operational relevance and basis in known sleep, circadian, and fatigue science. Pursue identified gaps and changes to ensure optimal benefits, including new approaches.

*PPR/FRMO3.* Evaluate existing, relevant CAMI fatigue research to identify opportunities for application across FRM activities. Pursue and apply/translate relevant findings into operational practice where appropriate.

*PPR/FRMO4.* Develop a strategic plan for CAMI fatigue-related research, including air traffic-related projects, that includes reactive and proactive activities. Identify explicit operational outcomes to be addressed when research findings become available.

*PPR/FRMO5.* Develop and implement a communication plan that transfers relevant CAMI findings to appropriate internal FAA groups in an ongoing manner.

*PPR/FRMO6.* Organize a small annual external advisory group meeting to review the CAMI ATC fatigue-related strategic plan, research projects, findings, application opportunities, and to help identify potential future research. The advisory group should include relevant stakeholders as well as subject matter experts.

*PPR/FRMO7.* Review/evaluate FRMS activities to determine if they meet explicit FAA FRM objectives, including their operational relevance and basis in known sleep, circadian, and fatigue science. Pursue identified gaps and changes to ensure optimal benefits, including new approaches.

*PPR/FRMO8.* Review current plans for revising ATSAP activities, form, etc. to ensure that any new efforts will enhance reporting and especially the use and value of reports/data.

*PPR/FRMO9.* Identify opportunities to apply available FRM activities/products beyond current use. Pursue and apply/translate relevant activities/products into operational practice where appropriate.

*PPR/FRMO10.* Determine appropriate resource needs for effective FRMS activities, including number of personnel, funding, etc.

*PPR/FRMO11.* Organize a small annual external advisory group meeting to review FRMS activities, expected outcomes, application opportunities, program effectiveness, and to help identify potential future projects. The advisory group should include relevant stakeholders as well as subject matter experts.

*PPR/FRMO12.* Identify and employ a reporting structure that ensures relevant FAA leadership (e.g., Administrator, Deputy Administrator, ATO leaders, other safety stakeholders such as NATCA) remain informed on a regular basis (e.g., quarterly) through multiple mechanisms (e.g., briefings, written materials) about ongoing, planned, and timely occurrences of ATC fatigue activities, issues, effectiveness, and plans.

### Section I(c): Health

The chronic exposure to sleep loss and circadian disruption created by shiftwork has significant adverse health consequences.  As illustrated in Figure W-2, "Shift work … leads to circadian misalignment and (consequential) sleep disruption. Circadian misalignment often manifests between behavioral and environmental cycles and the central pacemaker in the suprachiasmatic nucleus (SCN) and between behavioral and peripheral circadian oscillators found in virtually every organ and cell of the body. Internal desynchrony occurs between peripheral oscillators and the SCN, and among organs, cells and clock genes." Circadian misalignment and sleep disruption have been implicated in numerous adverse health outcomes, as illustrated in Figure W-2 adapted from a study on the health consequences of circadian disruption .[23] *This is another example of how there will be continued fatigue and health risks created by around-the-clock shiftwork demands, even when optimal staffing levels are attained.*

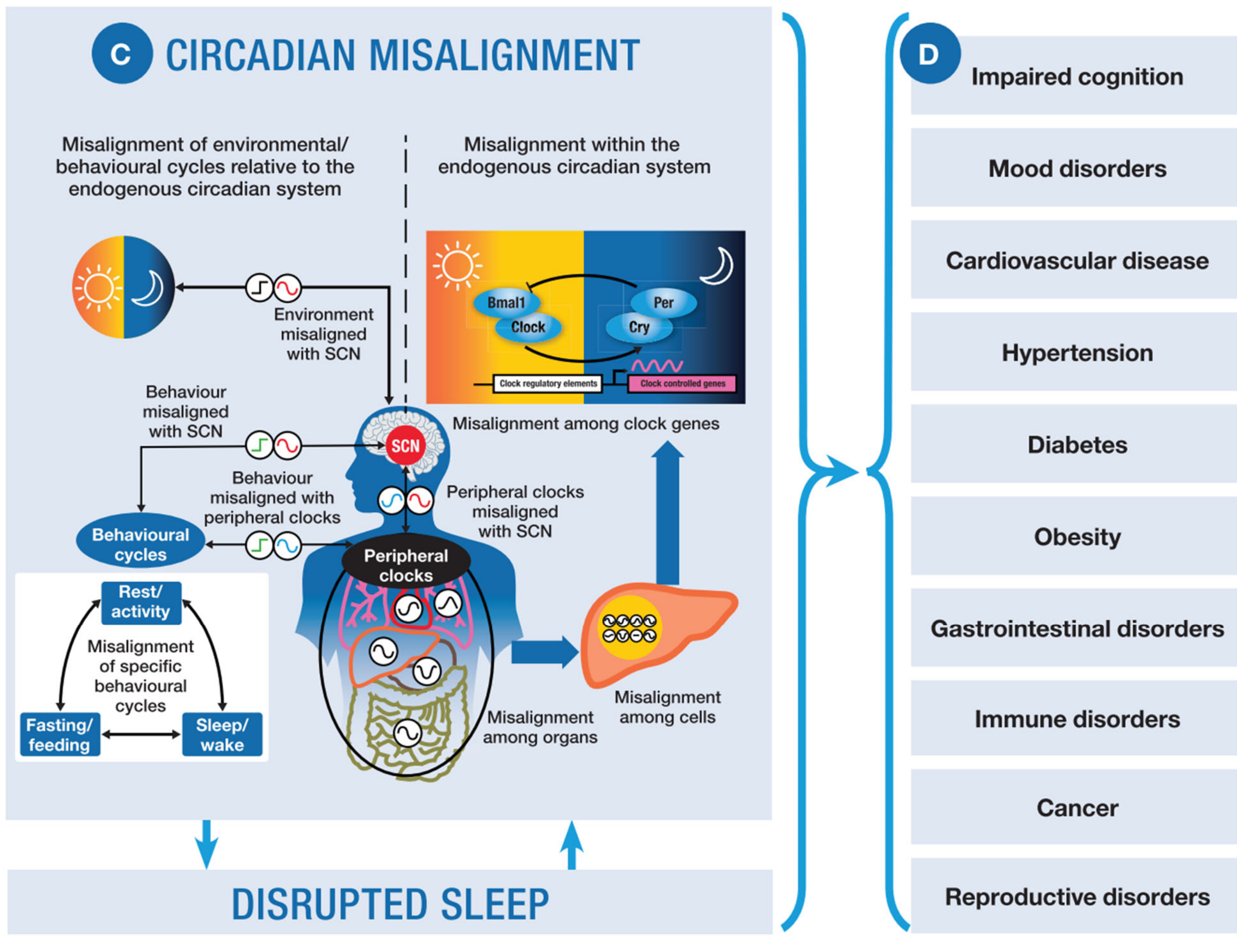


*Figure W- 2*

*Sleep disorders.* There are 59 sleep disorders listed in the *International Classification of Sleep Disorders* (ICSD-3) third edition published in 2014.[24] In ICSD-3, there are seven major categories addressed: 1) insomnia, 2) sleep-related breathing disorders, 3) central disorders of hypersomnolence, 4) circadian rhythm sleep-wake disorders, 5) parasomnias, 6) sleep-related movement disorders, and 7) other sleep disorders. Three examples demonstrate the relevance of sleep disorders to managing fatigue risk in controllers.

*Sleep apnea* is perhaps one of the most visible sleep disorders in society today. Obstructive sleep apnea (OSA) is characterized by complete or partial obstructions of the upper airway that repeat throughout the sleep period. This can result in full cessation of breathing (apneas), reduced breathing (hypopneas), and arousals associated with efforts to resume breathing. [25] There are 23 different diagnostic categories within sleep-related breathing. The continual arousals during sleep to resume breathing is typically associated with excessive sleepiness that results in performance decrements (including in the workplace) and crashes as well as other negative health outcomes (e.g., increased risk for heart attacks, stroke).[26] Estimates indicate that mild OSA likely affects 20% of adults though some studies suggest the prevalence may be up to 29% with differing risk associated with obesity, age, race/ethnicity, and comorbidities.[27] There are a variety of effective treatments for sleep apnea.[28]

*Insomnia* is described in ICSD-3 as "persistent sleep difficulty despite adequate opportunity and circumstances for sleep."[25] The complaints may involve difficulty getting to sleep, staying asleep or waking up too early and being unable to fall back to sleep with disturbances occurring at least three nights a week for three months. For diagnosis, the sleep complaint must be associated with some daytime disturbance, such as fatigue, problems concentrating or disturbed mood. Generally, about 30% of the U.S. population report insomnia symptoms though this drops to 10% - 28% with frequent, moderate or severe symptoms, and to 10% when including daytime consequences.[29] Insomnia has been found to be associated with occupational outcomes, job stress, depression, anxiety, and burnout.[26, 29] There are a variety of effective treatments for insomnia.[30-35]

*Shiftwork sleep disorder* "involves complaints of insomnia during the sleep period and/or excessive sleepiness during the wake period that is directly linked to shift-work exposure." "These deficits can adversely affect job performance, driving safety, quality of life, work satisfaction, and health." Prevalence estimates for the disorder range from 14% – 32% in night shift workers, to estimates of 8% - 26% among rotating shift workers.[36] Besides the formal diagnostic category for shiftwork sleep disorder, there are a variety of other well-established consequences of shiftwork, including insufficient sleep, excessive sleepiness, sleep disturbance, fatigue/sleepiness-related accidents and incidents, motor vehicle crashes, workplace incidents and accidents, work productivity, health effects, mental health effects, and quality of life. There are a variety of interventions used to address shift work generally and shiftwork sleep disorder specifically.[36]

These are medical conditions that can have a diverse array of adverse effects across an individual's life. Beyond these three examples, there are 56 other sleep disorder diagnostic categories. In some cases, individuals may be unaware of the condition, minimize its effects or attribute symptoms to other medical issues. Sleep disorders can be diagnosed and effectively treated.[28] These sleep disorders can have negative health and performance/safety outcomes that can be exacerbated by the demands of around-the-clock shiftwork.

*Mental health* issues are currently receiving increased attention as an active area of interest and study across aviation. There is a clear and close connection between sleep and mental health and well-being. Sleep disturbances can be a symptom/outcome of psychological concerns/mental health conditions or triggers to mental health events. Sleep can have effects on, or be affected by, emotions, anxiety, depression, substance abuse, and other mental health conditions.[37-42]

### *Strengths*

The FAA has established protocols and guidance to address medical conditions among controllers (FAA Order 3930.3, Air Traffic Control Specialist Health Program; Title 14 CFR Part 65 and Part 67). Therefore, established mechanisms are in place to handle healthcare procedures, including associated privacy requirements.

The ATO FRMS has previously provided some educational materials on sleep disorders, including their diagnosis and treatment. The FRMS provides one existing mechanism for distributing educational material and specific guidance on sleep disorder diagnosis and treatment.

*Risks*
Given the potential for significant negative health outcomes, performance and safety decrements, and mental health consequences, a more robust focus on sleep disorders information, diagnosis, and treatment would address gaps in current health/medical efforts. Many individuals with sleep disturbances or sleep disorders are unaware of these conditions, minimize them or make attributions to other causal factors. These sleep disorders are existing medical conditions that can affect health outcomes, performance, safety, and mental health deserving of diagnosis and effective treatment.

*Health Opportunities (HO)*
*HO1.* Enhance efforts through multiple mechanisms to provide education, guidance, and resources to understand and access the sleep disorders diagnosis and treatment process, including accredited evaluation centers. Pursue new information mechanisms for implementation. Ensure that provided health insurance programs cover sleep disorders diagnosis and treatment.

*HO2.* Evaluate data sources to examine whether current sleep disorders diagnosis and treatment rates approximate expected prevalence rates.

*HO3.* Ensure that current efforts to understand and address mental health issues in aviation include the air traffic controller population and reflects relevant information and actions related to sleep, circadian factors, and sleep disorders.

## Section I(d): Other Factors

Three other factors will be addressed briefly: cumulative/long-term effects, age considerations, and funding.

*Cumulative/long-term effects.* There are not sufficient air traffic controller findings to specifically extrapolate the cumulative/long-term effects of working six or more consecutive days, for consecutive weeks, months, and years. It is clear from short-term sleep debt findings that sleep loss will accumulate over time and that there are long-term negative effects of shiftwork on vigilance and performance,[43] and related to increased risk for cancer,[44] [45]cardiometabolic disorders, and obesity.[46] How these cumulative/long-term effects specifically affect air traffic controller work performance, safety, health, post-retirement or mental health are currently difficult to quantify though likely detrimental.

*Age effects.* Given the restricted age range for controllers, 30 years old or below to apply and retirement at age 56, fewer age-related sleep and circadian effects would be expected. However, sleep and circadian factors do change with age and could affect resiliency to shift work effects.[28]

*Funding.* As referenced in the SRT, funding is an obvious and critical issue to be addressed with a direct effect on NAS safety. This includes providing sufficient resources (including people, programs, and research) to effectively address known fatigue risks within ATO.

*Strengths*

CAMI provides the expertise and resources to examine cumulative/long-term effects, recovery time off, and age considerations within research studies and through specific projects evaluating these factors. The FRMS efforts provide one mechanism to distribute findings and generally highlight these issues among relevant groups.

There are established mechanisms to acknowledge people, program, and research needs to address ATO fatigue issues in budgets and requests to Congress.

*Risks*

Dismissing or minimizing cumulative/long-term effects and age considerations without specific or sufficient data creates potential risks that could emerge in system, facility or individual operations.

As identified by the SRT, sufficient and consistent funding is fundamental to NAS safety, including the effective management of fatigue risks.

*Other Factors Opportunities (OFO)*

*OFO1.* Examine the cumulative/long-term effects, recovery time off, and age considerations in previous (where available), current, and future air traffic controller research projects. Create a database to accumulate relevant findings from research and pursue opportunities to translate them into operational use. Utilize CAMI expertise, resources, and data whenever possible to review and research these issues.

*OFO2.* Construct and pursue a budget to effectively support ATO fatigue activities throughout the FAA to include at a minimum, people, programs, and research.

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# Section II: Work Requirements

ATC work requirements can influence and interact with fatigue in many ways. The cognitive demands required to achieve the safe navigation of aircraft through the NAS are complex and susceptible to fatigue-related lapses and errors. This is particularly apparent during periods of high and low workload which interact with fatigue in a manner that increases the potential for mistakes. Large fluctuations in workload may lead to challenges with controller staffing utilization during a shift. Controllers also typically work in environments with unregulated lighting levels that can be dark and have the potential to dampen alertness. Although controllers are afforded opportunities for breaks, the facilities are typically inadequate for recuperative rest. Despite these challenges, there are many aspects of controller work requirements that could be mechanisms for effective changes that reduce fatigue.

## Section II(a): Cognitive Demands

*Strengths*

There are many standardized policies, procedures, and tools that are already in place that provide a safety net to minimize the impact of fatigue-related cognitive decrements. Air traffic control is a complex task that requires the use of multiple cognitive resources that are susceptible to fatigue. Controllers must build an ever-changing mental model of their designated area of responsibility by monitoring radar screens and other sources of information to detect and track aircraft and hazards.[1, 2, 3] Monitoring and detecting are simple tasks that require selective and sustained attention/vigilance and perception to achieve. Some of the earliest studies connecting fatigue to attentional failures evaluated radar controllers.[4] The findings of those and subsequent studies revealed that sustained attention wanes over time on task, time awake, and time of day, leading to attentional failures.[5] These cognitive demands have been well documented and time on position is nominally limited to two consecutive hours to allow time for controllers to "rejuvenate their mental acuity."[6] Limiting the duration of time on position is an important policy that allows for the recovery of cognitive resources.

While sustained attention is an important component of air traffic control, there are numerous other cognitive demands on controllers that can be affected by fatigue. For example, once a controller has identified the aircraft and hazards within the assigned operational area, the controller must calculate the trajectories of the aircraft to anticipate and predict potential conflicts or loss of separation with other aircraft and hazards.[1] This is critical for the prevention of runway incursions and maintenance of safe separation in-flight. Calculation and prediction of trajectories involves working memory, visuospatial memory, and executive function. These cognitive functions are also susceptible to fatigue, resulting in forgetting tasks and slowed information processing.[7] Even experienced controllers can miss up to 10% of potential conflicts.[8] Assistive technology to model trajectories and identify potential conflicts, such as the ASDE-X Taxiway Arrival Prediction and Arrival Runway Verification (ARV), which automatically detects and alerts controllers of some runway incursions, and Time-Based Flow Management (TBFM), which provides time-based metering to help controllers maintain separation, have been deployed to many air traffic facilities.[9] [10] The implementation of such conflict detection technologies is an important strength of the system that can assist controllers in identifying potential hazards that could be missed due to fatigue.

Another critical element of air traffic control is the maintenance of effective and efficient communication with other controllers and pilots. Once a controller develops a plan, s/he must communicate orders to pilots and confirm that the orders were received and executed.[1] This requires language and verbal skills and perception of feedback, all of which can be degraded by fatigue.[11] The FAA has long-standing procedures that require cross-checking for each communication, utilizing specific phraseology, a phonetic alphabet, and repetition of orders (JO 7110.65W). Maintenance of FAA standard readback and cross-checking procedures provides redundancy that can help controllers and pilots catch mistakes prior to the execution of an order.

*Risks*

Despite the many policies, procedures, and tools that have been developed to mitigate the risk of fatigue-related cognitive failure, some vulnerabilities remain. A controller's operational area changes dynamically over time. Controllers continuously receive new aircraft as they enter their assigned airspace and hand off aircraft as they exit the airspace.[1] This handoff is typically completed via electronic messaging, whereby a controller sends a handoff request to the controller overseeing the airspace that the aircraft will enter, with the receiving controller acknowledging receipt of the aircraft electronically. Importantly, acknowledgment of handoffs can be suspended when a single controller is working during a phase of increased traffic between 0000 and 0500 (JO 7210.3.DD). As the controller initiates changes and as new aircraft enter and exit the airspace, the controller must continuously revise their mental model based on their position of responsibility. This requires the perception of new information and cognitive flexibility to revise plans and priorities based on new information.[12] The suspension of handoff acknowledgements during the night when cognitive deficits are most likely to occur, removes a potentially important layer of oversight between controllers.

When off-nominal situations occur, such as aircraft diversions or emergencies, controllers must select and pursue a course of action that appears to be most appropriate under the circumstances to provide the maximum assistance possible. Critical tasks that occur infrequently are particularly susceptible to fatigue-related cognitive failure. Specifically, attentional tunneling, whereby cognitive performance on secondary tasks worsens in order to divert cognitive resources to a primary task, can occur when an individual is fatigued.[13] There does not appear to be any process for transferring control of other aircraft (i.e., those still operating within the controller's operational area that are not affected by the off-nominal situation) to another controller in such situations.

Maintaining the safe separation of aircraft is critical for safety, but controllers must also *efficiently* move aircraft on the ground and through airspace. This requires the prioritization of tasks to optimize traffic flow using organizational strategies, coding, tracking, and prospective memory.[1] For example, in some cases moving a few key aircraft will resolve conflicts and result in steady traffic flow. Slowed cognitive processing speed due to fatigue may result in inefficient movement of aircraft, leaving unnecessary gaps and causing delays. Implementing policies that minimize fatigue should help improve controller performance in general, though there are also technological solutions that could help controllers maximize their efficiency and minimize fatigue risk. Specifically, the Terminal Flight Data Manager (TFDM) is such a tool. TFDM replaces paper flight strips and provides decision-support tools to controllers, but is not scheduled to be fully deployed until 2028.[14] Having such technology available in all facilities sooner would help improve efficiency and address fatigue risks by standardizing the tools and information that controllers have available to optimize traffic flow.

### *Cognitive Demands Opportunities (CDO)*

*CDO1.* Re-assess controller time on position limits to determine whether a shorter or longer duration is appropriate given current technology, traffic levels, environmental factors, and time of day. Determine whether a fixed time on position limit (i.e., nominally two hours) is appropriate for all types of air traffic facilities, regions, and time of day. This could be done through a dedicated study or possibly by using existing data from air traffic facilities.

*CDO2.* Identify and implement procedures that allow controllers to acknowledge the handoff of an aircraft during the midnight shift that do not further increase workload.

*CDO3.* Develop specific procedures, decision aids, or tools to assist controllers during infrequent, critical operations.

*CDO4.* Identify ways to expeditiously deploy controller-assist tools across all air traffic facilities.

## Section II(b): Workload

### *Strengths*

Controller workload can fluctuate dramatically over the course of a work shift. Processing speed and time pressure increases or decreases based on the traffic volume in the operational area, weather, prioritization of aircraft, and other factors. As traffic fluctuates, the number of control positions changes. When traffic volume increases, a single position may be staffed with two or three controllers.[3] For example, in Air Route Traffic Control Centers (ARTCC) facilities, the lead controller will be designated the radar, or "R-side" controller, with support from a radar associate or "D-side" controller. In this case, the radar controller is responsible for maintaining safe separation between aircraft and communicating with other controllers and pilots, while the D-side controller assists by planning traffic flow within a sector. If sector traffic increases further, a third, tracker controller may be added to the position to assist. Similar procedures exist in tower facilities, where a local controller may be assisted by a local assist or cab-coordinator. Having defined roles that allow a second or third controller to assist a primary controller during surge operations is a major strength that enables facilities to meet traffic demands without overloading a single controller.

### *Risks*

While having procedures to increase staffing when needed is important, supervisors must track and predict traffic fluctuations in order to ensure a sufficient number of controllers are available to staff positions when a surge in traffic is expected. The supervisor within an operational area will use the Monitor Alert Parameters (MAP) program to track traffic flow and visualize how traffic will fluctuate throughout the shift in order to aid in planning for traffic surges. However, this tool is in the process of being retired with no plan for replacement. The loss of this tool could increase workload for supervisors and potentially result in insufficient or inefficient responses to workload fluctuations.

The procedures that are currently in place to manage changes in workload throughout the day rely on having sufficient controllers at work to react to changes in traffic. The way that these procedures are currently implemented may inadvertently introduce new risks given workforce issues. For example, due to workforce staffing shortages, the D-side or local-assist position may be staffed by a trainee who is not fully certified to work the position alone. This has the potential to increase workload or cause distraction for the R-side controller, who may need to spend time double-checking or refining the input from the trainee D-side controller. Similarly, regularly utilizing trainees to staff positions may decrease their available training time and ultimately increase the time that it takes for them to become certified on all positions.

Similarly, when traffic volume or complexity increases and no trainee or certified controller is available to staff the second position, a supervisor may need to assist, leaving an operational area without oversight. In some cases, often overnight, a controller may simply take on the additional workload alone. Excessive workload results in inefficient operations, whereby controllers lose mental capacity and cannot handle as much traffic, especially when they are fatigued.[15] [16] This greatly increases the potential that a controller could miss critical information and raises the risk of the controller making a fatigue-related error.

While technological solutions may help with some of these fatigue-related risks, such as NextGen advancements, NAS 2040, and other automation opportunities, they may also introduce new challenges. Some of the technological advancements that are in development include highly automated tools and decision aids. Such technology may help alleviate some of the workload pressure that controllers face during traffic surges. However, new technologies and automation tools can also introduce new workload issues, similar to how the management of uncrewed aerial vehicles (UAVs) increases workload.[3] It is unclear exactly how future automated tools and the expansion of UAV operations will influence controller workload and complexity. It has been shown that significant increases in automation can introduce new fatigue-related challenges.[17] While UAV operations have the potential to further strain an already stressed system, major advances in automation technologies also have the potential to introduce work underload. Work underload can unmask latent sleepiness, leading to more involuntary sleep episodes and lapses of attention, thereby increasing the risk of a fatigue-related error.[17] [18] Therefore, automation should not be considered as a panacea for air traffic controller workload challenges or managing fatigue risks.

### *Workload Opportunities (WO)*

*WO1.* Maintain and enhance the MAP tool or replace it with a tool (existing or through development) that provides real-time traffic forecasting.

*WO2.* Identify methods to maximize the availability of controllers to accommodate surges in traffic. For example, this could be accomplished through alternate schedule designs or strategic utilization of part-time controllers or trainees.

*WO3*. Evaluate how controllers engage with efforts in progress by the FAA, such as NextGen and NAS 2040 advancements, to identify any unintended interactions with fatigue prior to deployment. For example, require that the development of new tools include fatigue assessments as part of human-in-the-loop testing.

## Section II(c): Controller Staffing Utilization

### *Strengths*

Most air traffic control facilities experience peak air traffic volume during the day and evening (approximately between 0600 and 2300), with a significant reduction in traffic during the midnight shifts (approximately between 2300 and 0600). Differences in traffic volume are a major factor in determining controller staffing needs by time of day. The higher traffic volume expected during the day and lower volume expected at night at most air traffic facilities means fewer controllers are scheduled during midnight shifts. This reduced staffing results in changes to the work requirements for controllers on midnight shifts that often differ significantly from day shifts. During midnight shifts, control positions are typically combined, so that one En Route or Terminal Radar Approach Control (TRACON) controller is assigned a greater operational area to manage. Similarly, tower controller responsibilities are consolidated so that multiple sections of the airport are managed by one controller, or the tower might close overnight, transferring responsibility to another facility. Scheduling fewer controllers at night when traffic is low reduces the number of midnight shifts that must be staffed, thereby allowing more controllers the opportunity for sleep at night throughout a work week.

Controllers are limited to 10 consecutive hours of operational duty within 24 consecutive hours and are provided with a break "to rejuvenate their mental acuity" after two hours.[6] During the day, the timing of operational tasks relative to these breaks is typically determined by the supervisor. At night, the division of labor and rest break timing may be determined between controllers or by the controller-in-charge. Longer breaks are allowed during midnight shifts in order to enable controllers to obtain "recuperative rest." The FAA allowance for controllers to take a recuperative rest break is an important component in helping controllers manage their fatigue, especially during midnight shifts (JO 7210.3DD).

When a controller is unable to obtain sufficient quality and quantity of sleep before a work shift, fatigue may rise to a level that makes it difficult for the controller to complete operational duties. In such cases, controllers may declare themselves unfit for duty due to being fatigued.[6] When this occurs, the fatigued controller may take sick or annual leave or may request to be assigned non-operational duties. Controllers self-declaring fatigue are asked to file a report as part of the voluntary ATSAP, within 24 hours of the event. Maintaining a policy that allows controllers to be able to declare themselves fatigued when they feel that they are not fit for duty is an important component of FRM. The FAA has been at the forefront in recognizing that employees in safety-sensitive occupations must have the ability to declare themselves unfit for duty due to fatigue (AC 120-103A). An additional strength that is somewhat unique to the air traffic control environment is that controllers may declare that they are no longer fatigued and return to work. This flexible policy allows for the possibility that a controller could return to work after recovering from fatigue.

*Risks*

The way that schedules are created directly influences how many air traffic controllers will be available at any point in time during a shift. The process for determining controller staffing needs and building schedules is disconnected from forecasts of overall controller staffing needs (Figure WR-1). Hiring is determined according to the Staffing Standard described in the Controller Workforce Plan (CWP),[19] while guidelines for the number of controllers required on a given day at a given facility are generated from the CRWG estimates of need.[20] There are clearly not enough controllers to meet either of these controller staffing targets; however, the difference between these numbers generates confusion and should be reconciled. The CRWG targets are used to determine how many controllers should be allocated to a facility. ATC shift guidelines are then negotiated by the facility representative and air traffic manager at each facility to determine how many air traffic controllers should be scheduled in an operational area at a given point in time. This information is used to design schedules; however, it also appears that schedules are built in a manner that strongly accounts for controller preferences at each facility (e.g., taking into account commuting, childcare needs, etc.). These factors are important to include as scheduling constraints but may result in controller staffing inefficiencies if not balanced against actual staffing needs based on workload (e.g., could result in too many staff at one time of day and not enough staff at another time of day). In addition, schedules are released at least 28 days in advance, with most controllers working a fixed rotation that includes planned overtime. Creating schedules in this manner, whereby schedules are determined far in advance, allows little flexibility to accommodate dynamic changes in traffic over the course of 24 hours. This reduces a facility's ability to react to disruptions in traffic flow due to weather and other factors, potentially resulting in an insufficient number of controllers available to meet high demand.

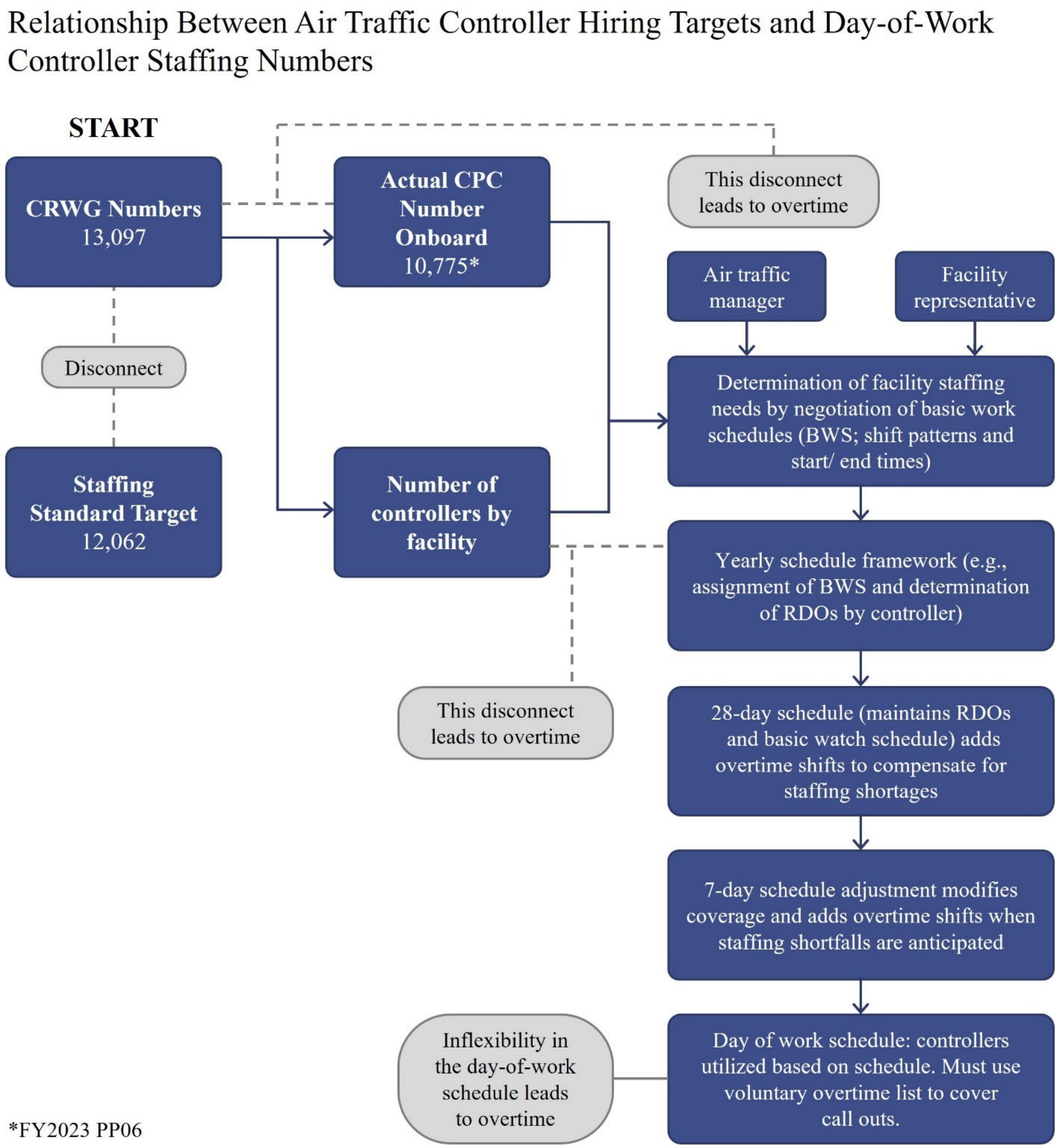


*Figure WR- 1*

One factor that reduces the number of controllers that are available on a given shift is the need to accommodate the time that controllers spend performing non-operational duties, such as training, testing new tools and technologies, and supporting safety programs, like ATSAP. The model used to inform the Staffing Standard does not incorporate time for ancillary duties, which means that overtime may need to be scheduled to accommodate these activities or they may not be performed at all. The CRWG identified 11 subcategories of work categorized as "other duties" in historical scheduling data.[20] The CRWG also determined that controllers working at understaffed facilities are often unable to complete training and other non-operational duties due to insufficient staffing, requiring a waiver from these requirements. Committing time to these non-operational duties is important to support controllers' development, though it is unclear how much time is dedicated to each of these activities by controller, facility, or across the organization. It is also unclear when such activities occur (e.g., within a shift, as a separate dedicated shift, as overtime, etc.). Having this information is critical for staffing utilization and is also key to ensuring that enough controllers are hired to accommodate all work activities.

Another factor that should be realistically accounted for by the Staffing Standard or CRWG controller staffing estimates is the incorporation of the actual duration of recuperative rest breaks into forecast models. The current FAA Order and CBA do not specify a minimum or maximum duration for recuperative rest[6] and there are no consistent or documented approaches describing how controllers actually manage tasks and recuperative rest breaks, especially during midnight shifts. This is important for workforce need estimates and also to ensure that controllers are able to get sufficient recuperative rest to maintain fitness for duty. During the night, there may only be two controllers working in a given operational area. In many cases, a manager is not present overnight and the shift is managed by a controller who is designated the 'controller in charge' (JO 7210.632A). In some cases, it appears that controllers will plan the timing of recuperative rest breaks with the other controller(s) on shift in order to allow each controller an extended recuperative rest period. Such strategies are used to compensate for insufficient and poorly timed sleep opportunities between shifts. Therefore, recuperative rest breaks are a critical factor that make it possible for controllers to maintain fitness for duty despite challenging schedules and overtime.

The lack of formal guidance regarding when and how controllers should optimize recuperative rest breaks creates a potential fatigue risk when a controller could be left without a sufficient recuperative rest break. For example, during midnight shifts, the unexpected absence of a controller due to a sick call has the potential to leave the remaining controller(s) without the ability to achieve a recuperative rest break. This can place an additional burden on the remaining controller(s), who may be relying on the informal system of determining rest break timing to ensure fitness for duty. When a controller is unavailable to work a scheduled shift and no replacement is available, controllers may be left with little to no recuperative rest break opportunity and a potentially challenging workload. This also has the potential to leave the remaining controller(s) with no ability to self-declare being unfit for duty due to fatigue, increasing the potential that a controller could make a fatigue-related error.

While there are no formal procedures for determining when and how controllers should take recuperative rest breaks, there are some work requirements that influence controllers' time on position during the midnight shift. Due to the many differences between day and night shifts, the FAA issued a memo indicating that controllers on midnight shifts are not allowed to combine positions down to a single controller for the first 90 minutes of the shift (or until 0130, whichever is later) and are required to "decombine shifts as traffic volume increases" (JO 7210.632A). While this memo appears to be intended to ensure that the controllers on a midnight shift work together to gain situational awareness before one of them takes a break, there is not a clear rationale for the 90-minute threshold. In addition, combining positions at a time when fatigue is greatest (i.e., in the middle of the night) increases the potential that a controller could miss critical information, especially in cases when traffic volume is displaced into the midnight shift (e.g., delays due to weather, airport construction, etc.). In order to ensure sufficient controllers are available to handle increases in workload overnight, the CBA indicates that employees are subject to recall from a recuperative rest break when needed. This may result in a controller having insufficient rest or recovery time from the recuperative rest break before assuming duties. In 2010, the Article 55 work group recommended a provision that rest breaks last 2.5 hours on midnight shifts to account for these issues.[21]

Decades of fatigue risk management research have established the effectiveness of recuperative rest breaks to improve performance and alertness and the best practices for optimizing recuperative rest timing, duration, and recovery to maximize cognitive function.[22] FAA JO 7210.3.DD explicitly prohibits sleep during any period when duties are assigned. This wording may inadvertently dissuade controllers from sleeping during recuperative rest breaks. Sleep is the best remedy for the sleep loss that results from shiftwork schedules. Other countermeasures (e.g., caffeine and activity breaks) do not provide the same level of benefits or lasting effects as sleep in counteracting the effects of fatigue.[23]

Although controllers have the ability to declare themselves fatigued when they are not able to obtain sufficient recuperative rest, some elements of the program could be improved. For example, controllers are allowed to continue working on non-operational duties when they declare themselves fatigued. However, a fatigued controller may not perform these ancillary duties to the expected high standards due to the effects of fatigue. In addition, a controller who continues to work while fatigued will have little to no opportunity to recover, which may influence their fatigue level during subsequent shifts. Another issue with the fatigue reporting program is that the process of ATSAP reporting appears to provide a mechanism whereby controllers could face punitive consequences for self-declaring fatigue. Specifically, the fatigue report may not be accepted if a committee determines that the employee knew or should have known about non-compliance with directives. This may discourage controllers from declaring themselves fatigued and instead, work through a shift with potential performance decrements. Despite these issues, surveillance of fatigue reporting has the potential to address fatigue risks and enable targeted interventions. However, fatigue calls are currently only tracked via ATSAP reports, making it difficult to monitor when, where, and how fatigue calls occur. Better systems to track fatigue calls would allow for the identification and mitigation of sources of fatigue (e.g., schedule-related, education-related, and fatigue due to personal factors).

### *Controller Staffing Utilization Opportunities (CSUO)*

*CSUO1.* Quantify how often scheduled traffic is delayed, leading to increased workload during midnight shifts. Identify and implement methods to support traffic surges during midnight shifts. For example, this could be accomplished by maintaining an option to extend controllers on a swing shift or schedule designs that provide more overlap between shifts.

*CSUO2.* Identify ways that controllers can be re-distributed within a day for a limited number of shifts so that staffing can be adjusted to meet traffic demands. For example, this might involve converting one shift a week to be "on reserve" or scheduling a shift to start within a range of time at the discretion of the manager. It may also be useful to schedule overtime in partial shifts, rather than full shifts to cover episodes of high workload.

*CSUO3.* Refine controller staffing models to better reflect actual work conditions so that they can be used to determine workforce requirements and to guide schedules. Specifically, this should include such factors as actual break durations, appropriate accounting for non-operational duties, adjustments for additional workload factors at a given air traffic facility, etc.

*CSUO4.* Determine how much time controllers dedicate to ancillary, non-operational assignments. Such information would guide better workforce needs, scheduling decisions, and controller staffing utilization. For example, there may be ways for supervisors to assign such activities during periods of low traffic as opposed to scheduled activities that take controllers off position without regard for traffic activity. Such solutions may enable the recovery of some training time at understaffed facilities.

*CSUO5*. Evaluate and determine if there are effective ways to monitor alertness/fatigue levels when positions are combined and managed by a single controller. For example, this might be done through controller self-assessments, validated fitness-for-duty tests, or through passive monitoring by developing tools or technologies that identify indicators of fatigue from operational data.

*CSUO6.* Specify a minimum duration for recuperative rest breaks for day, evening, and midnight shifts so that controllers can obtain a guaranteed rest duration that also allows time for recovery from the break.

*CSUO7.* Provide explicit FRM education and guidance on how to maximize the benefits of recuperative rest breaks.

*CSUO8.* Recuperative rest breaks may also be beneficial during day or evening shifts. Ensure language and training for recuperative rest breaks is consistent and available across all shift types.

*CSUO9.* Identify approaches to support a guaranteed recuperative rest break for controllers who are working alone. For example, this may include formal procedures to extend a prior shift or advance a later shift, utilize 'reserve scheduling,' combine positions across facilities, or temporarily close a sector of airspace to ensure the controller is able to take a recuperative rest break of sufficient duration.

*CSUO10.* Consider clarifying the language that controllers may not sleep while "on position" including appropriate modifications for recuperative rest breaks.

*CSUO11.* Consider allowing controllers to take immediate recuperative rest when they declare themselves fatigued.

*CSUO12.* Consider designating a separate leave category so that fatigue declarations can be tracked more effectively.

*CSUO13.* Review, and where appropriate, reform the process by which controllers declare themselves fatigued so that it minimizes or eliminates potential punitive consequences to the controller.

*CSUO14.* Improve FRM education for controllers specifically related to the use of fatigue reports to enhance the identification of fatigue-related vulnerabilities (e.g., identify facilities where schedule-induced fatigue is elevated, employees with undiagnosed or untreated sleep disorders, etc.).

## Section II(d): Work Environment

### *Strengths*

The physical work environment in most control facilities appears to be mapped in a logical manner that enables controllers to effectively and efficiently work together. Control facilities have clearly defined workstations where controller positions are co-located for a given operational area. This allows for the maintenance of situational awareness and communication between controllers working in adjacent positions. There are also designated workstations to accommodate assisting controllers when surges occur. Supervisors are typically assigned a workspace that allows a clear view of all of the controllers working within an operational area. This allows supervisors to maintain situational awareness and provide additional support when needed.

Control facilities typically have a separate break room with comfortable seating, areas for eating, and recreation and where controllers may take their recuperative rest breaks.

### *Risks*

Some controllers must sit for extended periods of time, often in a dark, quiet environment, monitoring multiple screens that contain radar, weather, and other relevant information. The lighting levels in the air traffic control environment are typically set by agreements between local controllers and management. There are no nationwide requirements specifying an intensity or wavelength threshold for lighting levels in air traffic facilities. Historically, darker rooms were required in order to see radar screens, but that is no longer the case with modern technology, as is evidenced by tower controllers who use radar screens in a variety of lighting conditions. Lighting is important to enable the completion of operational tasks and light is a critical fatigue countermeasure that has a direct impact on human circadian rhythms and alertness.[24] Bright, short-wavelength (blue, ~680 nm) light exerts a strong alerting effect, while dim and long-wavelength light increases sleepiness and reduces cognitive performance. Maintaining a dark work environment, especially during nighttime operations, has the potential to increase fatigue and the risk of operational errors.

The quality of a recuperative rest break is dependent, in part, on the break environment. There do not appear to be any policies that specify what accommodations are required in rooms designated for recuperative rest. Break rooms may have windows that allow light to intrude and may not have sound attenuation. In addition, break rooms designated for recuperative rest may not have appropriate accommodations for such rest, such as recliners and couches that allow individuals to lie down. Standardizing the environmental conditions for recuperative rest break rooms would ensure that all controllers have the same opportunity for a quality rest break. In addition, designating specific rooms for recuperative rest and standardizing their accommodations would allow targeted fatigue education material regarding best practices for recuperative rest to be available where controllers can see and act on it.

The lighting in break rooms designated for eating and recreation is provided through standard government procurement. A study examining NASA mission controllers found that replacing standard lighting with bright, blue-enriched lighting in recreational break rooms improved controller alertness and performance on the night shift.[25] There are no policies describing lighting requirements for controller break facilities.

### *Work Environment Opportunities (WEO)*

*WEO1.* Identify, test, and deploy a standardized lighting level that allows for optimal alerting, while also assuring lighting is appropriate to meet task needs.

*WEO2.* Enhance the recuperative rest break rooms with consistent amenities between facilities, such as blackout curtains, white noise, and comfortable recliners. Separate recuperative rest areas from other work and active break areas.

*WEO3.* Deploy FRM education and training material describing best practices for recuperative rest throughout the break rooms so that controllers have easy access to relevant information.

*WEO4.* Identify, test, and deploy enhanced lighting in recreational break rooms to improve controller alertness and performance on the job.

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## Section III: Scheduling Practices

There are three core factors for consideration in the development and implementation of scheduling practices and schedules: operational requirements, employee needs and preferences, and biological needs (Figure SP-1). Every single day of the year, air traffic controllers are required to staff highly specialized positions within 313 facilities to maintain safe and efficient round-the-clock operations. These round-the-clock shiftwork schedules create conflicts for individuals who need to balance work with family and societal demands. And humans have biological needs for sleep and circadian stability that are compromised when work schedules conflict with these basic biologic functions.

Critical Design Factors for Scheduling Work in Round-the-Clock Operations

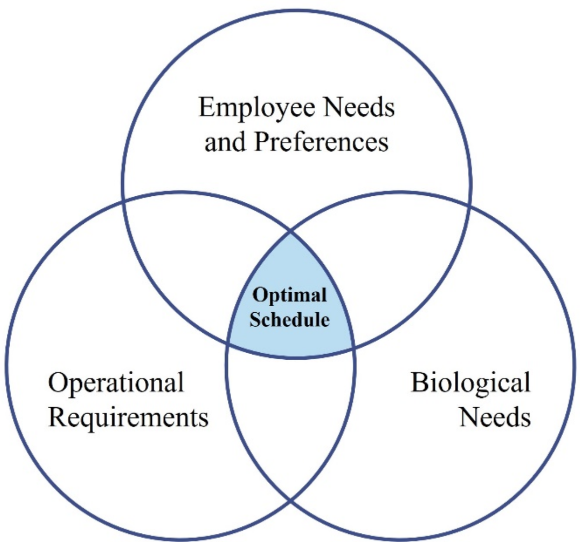


*Figure SP- 1*

For ATO to fulfill its mission, *operational requirements* are the primary consideration. Hence the critical, central role of staffing to ensure around-the-clock NAS operations. Then there is the level of specialization by area/position that adds complexity to schedule design. The workload and air traffic controller tasks involve intense vigilance, cognitive load, etc. that require breaks after 90-120 minutes to maintain performance levels. Added to this is the need for training, including on-the-job for trainees, as well as responding to weather changes, emergencies, and ancillary duties, and the work scheduling task becomes daunting. Clearly, safely and efficiently meeting the NAS around-the-clock operational requirements is a dynamic, complex task.

*Employee needs and preferences* are another consideration in the design and effective implementation of 24/7 work schedules. Air traffic controllers are central to providing safe and efficient NAS operations while also maintaining off-duty lives that allow them to meet societal demands, family needs, and other activities of daily living. The National Air Traffic Controllers Association (NATCA) represents air traffic controllers in negotiations with the FAA to establish a CBA that outlines an extensive array of detailed scheduling parameters. On several occasions, the FAA has surveyed controllers to understand their needs and preferences, including tasking by Congress for such evaluations (example in Appendix E).

The third consideration in the design and implementation of schedules and scheduling practices for 24/7 operations involves *biological needs*. Just like food, water, and air, all humans have a vital need for sleep. Disrupt sleep through acute sleep loss, a cumulative sleep debt, or sleep disorders and potentially all aspects of human capabilities can be degraded or impaired, including performance. It has been well-established that these performance decrements can lead to operational errors, incidents, and accidents.[1-6] The human circadian clock controls diverse biological, behavioral, performance, and mental health factors on a 24-hour basis, including the drive to sleep and wake. Disrupting this clock leads to sleep loss, performance decrements, and fatigue risks for operational errors, incidents, and accidents.[1-7] Rotating shifts, night work, direction of shift rotations, off-duty recovery needs, cumulative effects, and more represent the range of operational requirements that can disrupt sleep and circadian factors to increase fatigue risks in operational settings. Schedules and scheduling practices informed by the science known about these basic biological needs can provide a foundational structure that acknowledges and supports human biology rather than knowingly precipitate sleep and circadian disruptions. Appendix D provides more information on these basic biological needs.

## Section III(a): Operational Requirements

*Strengths*

The FAA and CAMI have conducted extensive research on a variety of relevant factors related to ATO operational requirements, employee needs and preferences, and biological needs. Some of this work has been described in the Workforce section of this report. This research and its findings are available to inform scheduling practices to ensure that actual schedules reflect these three areas of consideration.

Some aspects of the planned schedule are identified in advance. For example, according to the CBA, all controller vacation days must be posted and bid upon (by seniority) a year in advance, and all work schedules must be posted at least 28 days before the start of a work interval, with changes necessitated by operational requirements (but not overtime avoidance) allowed up to 7 days in advance. For pay purposes, the agency maintains records of when controllers actually started and ended work, and classifications as to when they worked regular days (Regular), when they were scheduled to regular days off (RDO), when they were scheduled to Time Not Worked (TNW), and when they were scheduled to work overtime (OT).

The FAA has pursued scheduling tools intended to support schedule creation at facilities by on-site supervisors. For example, a commercially available tool, Operational Planning and Scheduling (OPAS), was purchased (in 2010 at a cost of $17M) and another, Air Traffic Operational Management System (ATOMS), has been explored though not finalized.

*Risks*

While the FAA and CAMI, as well as other research groups, have generated a significant amount of data and findings related to diverse aspects of air traffic controller fatigue risks, it is unclear how much of this information has been incorporated into current scheduling practices. For example, some policy, CBA, MOUs, and local facility scheduling practices appear to conflict with research findings and known biological needs for sleep and circadian factors. There appear to be no explicit mechanisms to ensure that research findings and human biological needs are included in the discussions and deliberations regarding scheduling practices. If not included in real-time during discussions and deliberations, at least a formal review of regulatory, policy, CBA, MOUs, and local facility scheduling practices could identify fatigue-related strengths and risks associated with the proposals and practices.

While some aspects of *planned schedules* are identified in advance, *actual schedules* worked are tracked through pay mechanisms. The difference between planned vs. actual schedules worked is a critical variable to understand fatigue risk. *Planned schedules that reflect fatigue considerations can be different from actual schedules worked that introduce unaccounted or unintended fatigue risk variables.*

There are no national nominal work schedules for controllers. Scheduling practices and actual schedules are decentralized with management supervisors at each of the 313 ATO facilities negotiating locally with NATCA representatives to schedule the controllers assigned to that facility. The ATO does not maintain records centrally as to the nature of the work scheduling practices used at each facility, or the shifts to which each controller are scheduled 28 or 7 days prior to the start of the work interval. Anecdotally, each facility may have a variety of different actual schedules (e.g., 40-60) used to accommodate operational requirements and employee needs and preferences. Across the 313 system-wide facilities, this could represent thousands of schedule variations. Without centrally tracking these variations or ensuring that they are informed by known sleep and circadian factors there is the potential to further increase fatigue risks in the dynamic and complex ATO scheduling practices.

Regarding the potential scheduling tools, in 2018, the Office of Inspector General concluded that the: "FAA lacks a comprehensive plan that outlines how the Agency will deploy the scheduling tool. Specifically, FAA does not have a plan for when it will (1) complete its negotiations with NATCA regarding the implementation of [Air Traffic Operational Management System] ATOMS, (2) modify ATOMS to include scheduling capability, (3) deploy ATOMS at all facilities, and (4) train controllers how to use the new tool. Currently, FAA and NATCA are negotiating a Memorandum of Understanding (MOU) to address the ATOMS implementation. Still, it has been 8 years since [a commercially available tool, Operational Planning and Scheduling] OPAS was procured for testing purposes at a cost of $17 million, and 2 years since the [Collective Bargaining Agreement] CBA was signed [between the FAA and NATCA]. Yet FAA does not have a finalized plan that lists the dates, system needs, potential risks, and costs of deploying the scheduling tool at air traffic facilities. As a result, it is difficult for FAA to assess its own performance and to stay on track with development and implementation. FAA's decision to partially implement OPAS and ATOMS has increased the level of complexity, and what was expected to be an "off the shelf" acquisition has evolved into a customized effort with undefined capabilities, costs, and due dates. Furthermore, the ATOMS scheduling capability has not been field tested, and it is accompanied by additional risks—related to new requirements, programming, and training. For example, requirements may change over time, and the training and deployment schedule is currently unknown. As a result, FAA does not know the final cost or how long it will take to deploy a scheduling tool for the controller workforce."

"Ensuring adequate workforce planning for the Nation's air traffic controllers depends on the development of efficient work schedules. FAA and NATCA agreed to implement a standardized controller scheduling tool that would achieve this goal of developing and maintaining optimal schedules. However, FAA's decision to use both OPAS and ATOMS to manage and schedule controllers has delayed implementation indefinitely, raising the estimated final cost of both tools to $42.1 million. Until FAA actually starts to use these scheduling tools, it will be unable to track controller productivity and reduce operations costs at the Nation's air traffic facilities."[8]

As of March 2024, these scheduling tools have not been deployed and facility supervisors continue to schedule controllers manually. Given the known staffing levels below operational requirements, this increases the workload of supervisory staff, and reduces the efficiency of the overall operation.

Notably, commercial passenger carriers are constrained by more restrictive regulations in building schedules for pilots and cabin crew compared with controllers (14 CFR Part 117). The airlines are able to schedule thousands of personnel for thousands of flights on a month-to-month basis without violating those regulations. Unlike controller schedules, which involve fixed rotations, pilot schedules change each month. Airlines typically employ a preferential bidding system whereby crewmembers are able to bid on their schedules on a monthly basis. Furthermore, airline scheduling tools typically integrate biomathematical models that estimate fatigue levels based on predicted sleep and circadian elements of the schedule.[9] The integration of these biomathematical models allows airlines to go beyond regulations to proactively manage schedule-induced fatigue. There are likely many tools, technologies, and lessons learned from these operations that could be adopted or adapted to scheduling practices in the controller workforce.

### *Operational Requirements Opportunities (ORO)*

*ORO1.* Identify and use mechanisms to ensure that known sleep and circadian science as well as FAA/CAMI and other relevant research findings are used to provide input and guide policy, CBA, MOUs, and other scheduling practice efforts. These could include individuals, reports, briefings, etc. that are integrated into working groups or other mechanisms used to address scheduling practices and fatigue management.

*ORO2.* Create, analyze, and use a centralized database of schedules planned and actually worked that includes a national collection of the 313 ATO facilities' schedules and their variations.

*ORO3.* Develop national nominal ATO schedules that reflect the known sleep, circadian, and fatigue science with specific policies, procedures, and guidance for the circumstances and applications to create variations.

*ORO4*. Within an appropriately short timeframe, develop a strategic plan and explicit tactical milestones to determine and deploy a scheduling tool to support facility supervisors' scheduling practices. Incorporate a relevant fatigue risk modeling tool into the scheduling tool or as a component of scheduling procedures. Evaluate the scheduling tool and fatigue risk modeling predictions on a regular basis to ensure optimal effectiveness and value.

*ORO5.* Create and confirm scheduling practices meet operational requirements for safety and efficiency within a structure that provides basic support for sleep and circadian needs while minimizing or mitigating known fatigue risks.

## Section III(b): Employees Needs and Preferences

One schedule that receives attention when discussing controller fatigue risks is a counterclockwise rotating 2-2-1 schedule, sometimes referred to as the "rattler" (noted as such in the 2014 TRB Special Report, Number 314). In 2014, this TRB Special Report (Number 314) indicated that: "the counterclockwise rotating 2-2-1 schedule compresses the workweek (five shifts during four days followed by 80 hours off) and is thus popular among controllers."[10] Similar sentiments about the popularity of this schedule among controllers have been expressed in a number of government reports.[11, 12] However, since there is no central national tracking of schedules planned or actually worked, there were no published data available to determine the extent that this counterclockwise rotating 2-2-1 schedule is currently preferred or worked. Figure SP-2 illustrates this schedule.

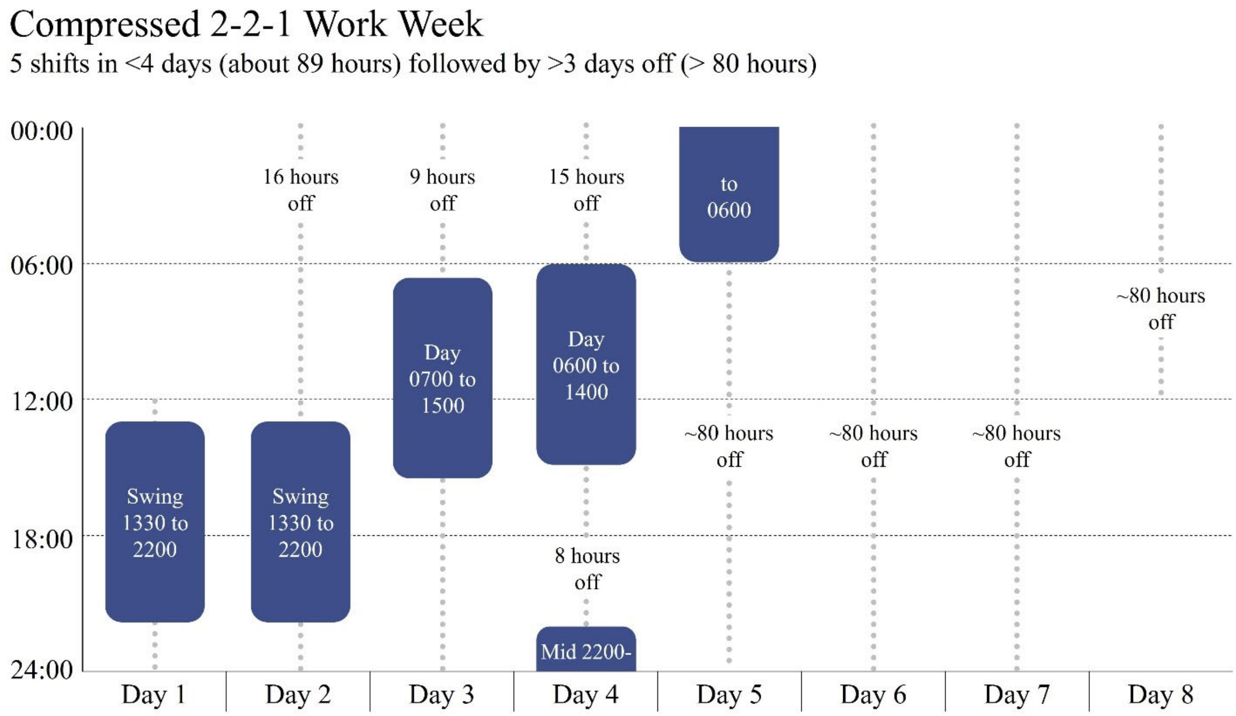


*Figure SP- 2*

In this schedule, there are two instances each week when controllers are nominally scheduled to return to work with only 8- to 9-hour intervals off between shifts; in practice, those 8- to 9-hour intervals between shifts may be even shorter when an individual is required to work later than scheduled, start earlier than planned, or both. The nominal schedule includes one instance when controllers are scheduled to return to work the night shift on the same date that they work a day shift (Day 4 in Figure SP-2). Generally, shift workers dislike such quick turnarounds, which may be why this schedule is relatively unique[13] in round-the-clock operations in the United States.

CAMI data from 2001 show that the counterclockwise rotating 2-2-1 schedule is associated with identified fatigue risks and—contrary to the often repeated statement of its popularity—has essential features that are unpopular with controllers and are difficult to manage.[14, 15] The 2001 CAMI study is perhaps the most comprehensive satisfaction assessment of controllers, a Congressionally-mandated, FAA-sponsored survey that was distributed from 1999 to 2000 to all

FAA personnel with an Air Traffic Control Specialist designation. According to the report,[15] more than 6,000 personnel were surveyed, including more than 4,000 controllers.

Specifically, in regards to the counterclockwise rotating 2-2-1 schedule in the 2001 survey, when respondents were asked about the disadvantages of the then-current shift work system, the main perceived disadvantages were related to fatigue. As indicated in the report, "Fatigue or sleep problems [were] by far the most frequently cited disadvantage of the shift system (86.5%)." Quick Turn Arounds were the most common complaint identified by the respondents working the counterclockwise rotating 2-2-1 schedule. This was followed by "Fatigue," "Lack of Sleep" and "Difficulty adjusting to sleep patterns". In response to another question, 164 controllers reported that "Quick turn arounds (8 hours between shifts) – causes fatigue and is dangerous." (excerpt of Table SP-1).[14]

**Table 59. Question 1.34: Main Disadvantages of Respondents' Shift System**

| RESPONSE CATEGORY | FREQUENCY |
|---|---|
| **Fatigue** | **5,217** |
| 1. Quick Turn Arounds (Less Than 8 Or 10 Hours Between Shifts–Causes Fatigue) | 1,765 |
| 2. Fatigue; generally tired | 1,266 |
| 3. Lack of sleep | 1,189 |
| 4. Difficulty adjusting to sleep patterns | 997 |

*Table SP- 1*

In the same 2001 survey, when asked about their preferred work schedule, the most common responses indicated that the respondents would prefer schedules with weeks or months of straight shifts before rotating onto alternative shifts (i.e., rotating much less frequently than every 1-2 days, as occurs on the counterclockwise rotating 2-2-1 schedule), as shown in the excerpt from SP-2 below: [14]

**Table 60. Question 1.39: Preferred Shift Schedule**

| RESPONSE CATEGORY | FREQUENCY |
|---|---|
| **Patterns of Start Times (Straight Times vs. Rotating Times)** | **854** |
| 1. Weeks of straight shifts alternating over weeks/months | 224 |
| 2. Straight shifts | 203 |
| 3. Rotation between two adjacent shift times | 122 |
| 4. Rotation with regressing (ascending) start times | 113 |
| 5. Week of straight shifts with one non-straight shift | 104 |
| 6. Rotating shifts – no preference indicated | 54 |
| 7. Rotation between two non-adjacent start times | 34 |

*Table SP- 2*

CAMI investigators published data from the 1999-2000 survey in 2001 that accounts for why controllers are excessively fatigued on the 2-2-1 schedule. They found that controllers reported sleeping an average of 8.03 hours before an afternoon shift but reported an average of only 3.51 hours of sleep before the midnight shift. These data are consistent with findings from a more recent 2012 NASA study that found controllers slept an average of 3.25 hours ($\pm$ 2.13 hours SD) during the 8-hour break between the end of the afternoon shift and the same-day start of the midnight shift, and 5.39 hours ($\pm$ 1.39 hours) before morning shifts that started before 0800.

The 2001 CAMI study[14, 15] provided in Appendix E revealed that overall, 62% of the more than 4,000 controller respondents reported difficulty sleeping before the midnight shift. Ninety percent of the respondents reported that they needed to take a nap while at work, and 71% found themselves about to “doze off” at work. These 2001 CAMI data are again consistent with data from the 2012 NASA study,[11] that reported: “Overall, 18% of current [Air Traffic Controller] 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." The 2001 CAMI study[14, 15] data provided in Appendix E noted that “67% of ATCS shift workers reported having trouble sleeping because of shift work [and] 46% of ATCS shift workers indicated that they often fall asleep unintentionally.”

The average sleep data in the 2001 CAMI study[14, 15] and the 2012 NASA[11] study are also comparable with a 1995 CAMI study from 95 Air Traffic Control Specialist (ATCS) volunteers from the Miami Air Route Traffic Control Center (ARTCC) who kept daily sleep-wake logs: “Total sleep time on the 2-2-1 schedule showed a characteristic decline from approximately 8 hours before the two afternoon shifts, to 5 hours before the two early morning shifts, to 2.4 hours before the midnight shift.”[13]

The 2001 CAMI study[14, 15] data provided in Appendix E found that reported sleep quality was rated most poorly (averaging only 1.3 on a 1-5 scale in which 5 was high) on the sleep between the day shift and the night shift on the counterclockwise rotating 2-2-1 schedule, worked by 92% of the respondents. The respondents felt least rested (average rating of 1) between midnight shifts and the least mentally sharp in terms of alertness and memory at the end of the midnight shift. The Report noted that mental sharpness “plummeted” on the same-day midnight shift inherent in the counterclockwise rotating 2-2-1 schedule, concluding that, “Mental sharpness is lowest during the midnight shift because at this time, shift workers must deal with the circadian low point for energy and alertness levels, and the effects of poor quality daytime sleep.”

On the counterclockwise rotating 2-2-1 schedule with midnight shifts, as shown in Appendix E, CAMI investigators reported in 2001 that 77% of the air traffic controllers reported that they had caught themselves about to doze off while at work; 79% of the air traffic controllers had sometimes, frequently or always had lapses of attention. Thirty-six percent of respondents reported they had actually fallen asleep at the wheel of a car while commuting on the midnight shift and this most often occurred on the commute home from the midnight shift. As noted by the authors: “This study shows that controllers are experiencing lapses of attention and/or falling asleep while driving to or from work. This incident rate is highest after working a midshift, with early morning shifts also being a concern.”

Six percent of the respondents reported an operational deviation in the past year, and 7% reported an operational error in the past year. Most respondents who had operational errors or deviations indicated that fatigue was a factor (51%) and that the fatigue was due to shift work (92%).

In another CAMI survey study conducted in 2000 with 210 controllers working in En Route Traffic Control Centers, the investigators reported the following results regarding questions about daytime sleepiness among those working the counterclockwise rotating 2-2-1 schedule: "To the question, "About how often do you feel tired or sleepy at work?" 1.0% reported never; 3.3% reported less than once a month; 13.8% reported once or twice a month; 25.7% reported once a week; 40.0% reported' two or three times a week; and 15.2% reported about every day (1.0% did not respond). In addition, 68.1% reported that they had caught themselves about to "doze off" while at work in the last year. Over half (52.9%) reported that they had taken naps while at work in the last year. Finally, 32.4% reported that they had fallen asleep while driving home from work in the last 6 months…. Over half of the sample in this study reported periods of severe fatigue or exhaustion."[13]

Some CAMI evaluations of the counterclockwise rotating 2-2-1 schedule have reported that some performance outcomes are either not different on this schedule[16] or better on the counterclockwise rotating 2-2-1 schedule compared to alternatives.[17] A report from a 1973 CAMI study concluded that "stress differences on the two rotation patterns (studied) were too slight to be of real significance and a choice between them would have to rest on managerial considerations rather than biomedical ones."[18] It is possible that one reason that the counterclockwise rotating 2-2-1 schedule has been preserved is because the results of these studies suggest that it is either not different or even superior to alternatives. However, a closer inspection of these studies reveals that the schedules that the counterclockwise rotating 2-2-1 schedule were compared against were rotations that would also be expected to induce significant fatigue. Specifically, the 1973 study compared the counterclockwise rotating 2-2-1 schedule against five consecutive night shifts while the more recent CAMI studies compared the counterclockwise rotating 2-2-1 schedule to eight- or ten-hour clockwise rotations. There are a number of alternative schedule designs that could be more effective in addressing fatigue during 24/7 operations that should be considered when exploring alternatives to the counterclockwise rotating 2-2-1 schedule.

*Strengths*

Several CAMI studies have provided considerable amounts of data through surveys and sleep-wake logs involving thousands of air traffic controllers and other controller designations. These data provide an understanding of reported fatigue risks and schedule preferences (Table 60).

Despite the complexity of scheduling 24-hour operations in air traffic control, the FAA and NATCA work closely together to accommodate many employee needs and preferences through the CBA negotiations and memos. These accommodations ensure that controllers have schedule predictability in the form of regular days off, some options for flexibility in the form of "flex time," and schedules that are adjusted for facility-specific concerns such as rush-hour traffic.

*Risks*

Results from multiple CAMI survey studies clearly demonstrate *reports* of fatigue risks among a high number of respondents, including the frequent experience of fatigue and sleepiness at work, falling asleep at work, fatigue-related operational deviances, fatigue-related operational errors, and sleepiness behind the wheel while commuting.

Respondents reported significantly disrupted sleep associated with shift schedules, including average sleep amounts of 2.4 - 3.51 hours before the midnight shift.

Respondents reported concerns about quick turn arounds and the counterclockwise rotating 2-2-1 schedule.

*Employees Needs and Preferences Opportunities (ENPO)*

*ENPO1.* Given that most of the data regarding scheduling preferences are about 25 years old, quickly conduct focused surveys to update this information and expand questions to reflect current circumstances and specific schedule features.

*ENPO2.* Ensure that available data (CAMI and others) regarding schedule preferences are included in discussions, deliberations, and decisions regarding potential changes in future scheduling practices. This should include written materials, briefings, and participation in working groups.

## Section III(c): Biological Needs: Sleep and Circadian Factors vs. Schedule Demands

There are two principal interacting biological regulatory processes relevant to fatigue risk in air traffic controller operations: the sleep homeostat and the circadian clocks in the brain and body. Further descriptions of these biological processes are provided in Appendix D. Sleep loss and circadian disruption can degrade or impair performance as well as increase the risk of adverse health consequences.[19-24]

The core features of a work schedule related to sleep and circadian factors include: 1) stability of the work schedule, to reduce the adverse effects of recurrent circadian disruption; 2) direction of shift rotation (clockwise vs. counterclockwise); 3) duration of work shifts to avoid buildup of acute sleep loss; 4) recovery time between shifts, required before another shift start to ensure adequate opportunity for sleep; 5) number of consecutive night shifts (cumulative effects); and 6) opportunity for recovery sleep every week, to reduce the cumulative sleep debt.

Effective scheduling practices must include sufficient off-duty periods for recovery sleep and other life activities (family, social, etc.). Diary and actigraph/activity data from CAMI and other research indicate that adequate sleep amounts can be obtained during some off-duty/recovery periods (e.g., night sleep opportunity), while others (e.g., day sleep, short turnarounds, early start times) can result in very short, inadequate sleep amounts. Obviously, it is essential to provide sufficient off-duty time to optimally manage the off-duty recovery opportunity. An insufficient off-duty period will create sleep loss even in situations when maximum sleep is obtained.

To allow direct examination of some scheduling factors, the FAA provided more than 700,000 lines of data reports for all controller shifts worked in December 2023 and January 2024. Due to the December holidays, initial analysis focused on data from 340,584 individual reports of work hours and days off recorded from 10,760 controllers during the month of January 2024 (December 31, 2023 to January 30, 2024). Additional analysis was conducted on data reports that the FAA subsequently provided for all controllers shifts *with operational duties* worked for the first 10 weeks of 2024, from December 31, 2023 through March 10, 2024 (Pay Periods 2 through 6).

The following data examined seven different aspects of controller work schedules: 1) average total hours worked, 2) hours on duty, 3) hours off between shifts, 4) hours between end of the evening shift and start of the morning shift, 5) hours between end of the day shift and same-day start of the midnight shift, 6) consecutive days of work, and 7) consecutive midnight shifts. Several individual examples illustrate actual schedules worked in the context of the sleep, circadian, and fatigue factors discussed in this report. *Further verification is needed for all of these findings and given the limits of the current dataset the results can* <u>*not*</u> *be generalized beyond the exploratory nature of this analysis. Also, while these data may describe 'what' happened, they do not explain the 'why' of specific circumstances and therefore interpretation is limited*.

During January 2024, on the average day across air traffic operations, the data that was provided showed that 703 controllers worked an overnight shift. On these shifts, 487 (69.3%) began the overnight shift on the same day that they had worked a day shift, that ended on the afternoon of the same day that they subsequently started the night shift. This is a unique feature of the counterclockwise rotating 2-2-1 schedule shown in Figure SP-2. *These data demonstrate that this counterclockwise rotating 2-2-1 schedule remains a common variant used by controllers nationwide to staff the night shift.* This conclusion was verified further by directly checking many schedules associated with this feature. It also is consistent with the 2012 NASA study that found: "Across all facilities, the dominant schedule [among FAA ATCs] was the counter-clockwise rapidly rotating [2-2-1 schedule] with midnights (RRM), which accounted for 61.4% of the 272 5-day schedules…."

In the first 10 weeks of 2024, the distribution of weekly work hours among controllers is illustrated in Figure SP-3 the "Average Weekly Hours Worked by Controllers in the First 10 Weeks of 2024". While 73.9% of the 10,363 controllers worked an aveage of 40 hours or fewer per week during the first 10 weeks of 2024, 26.1% of the controllers worked an average of 40 to 60 hours per week.

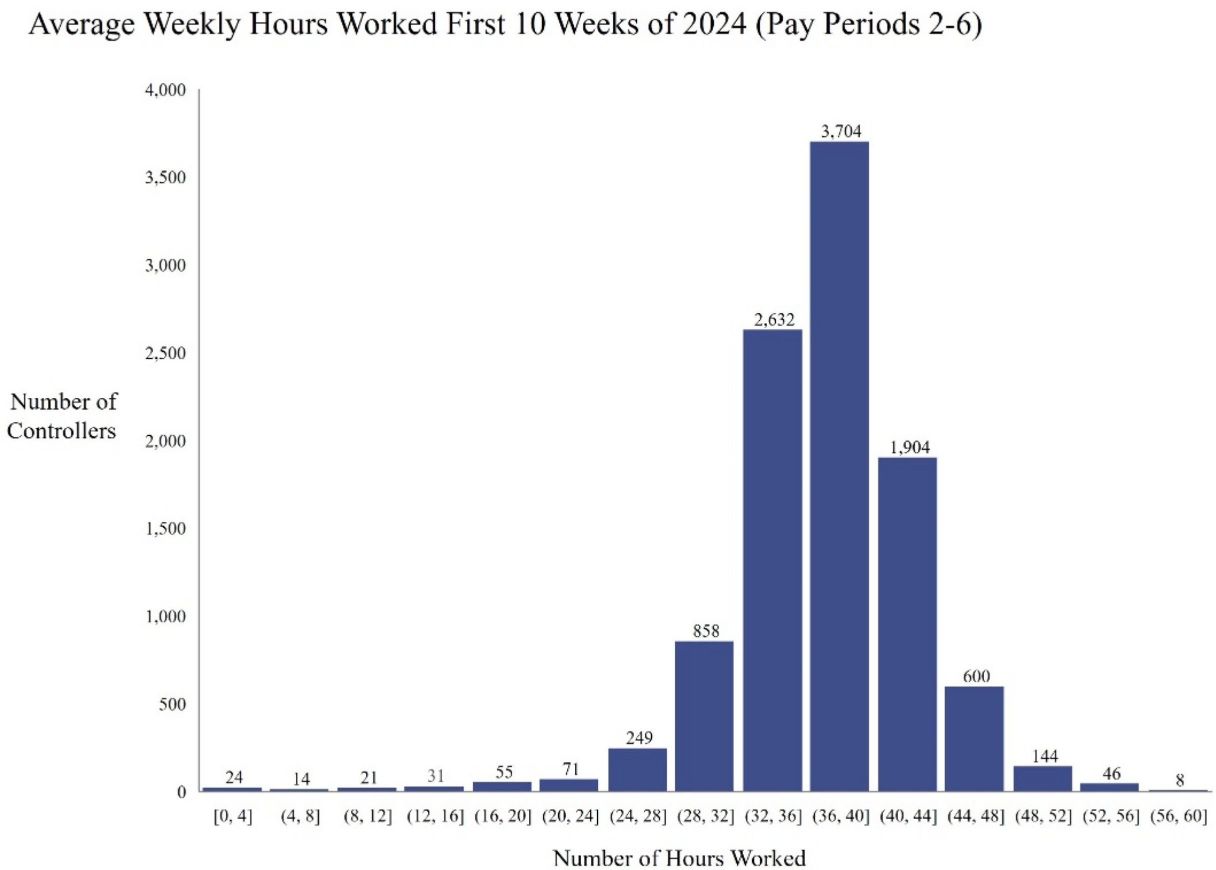


*Figure SP- 3*

During the first 10 weeks of 2024, the average operational shift duration most commonly worked by controllers was approximately 8 hours or fewer (74.3% of shifts), 25.6% were between 8 and 10 hours in duration, and 470 shifts (0.1%) worked were longer than 10 hours in duration, as shown in Figure SP-4.[25] *This finding suggests that there were many shifts that exceeded FAA Order 7210.3.DD, which limits consecutive operational duty to 10 hours. However, this should be verified in a larger and more comprehensive dataset.*

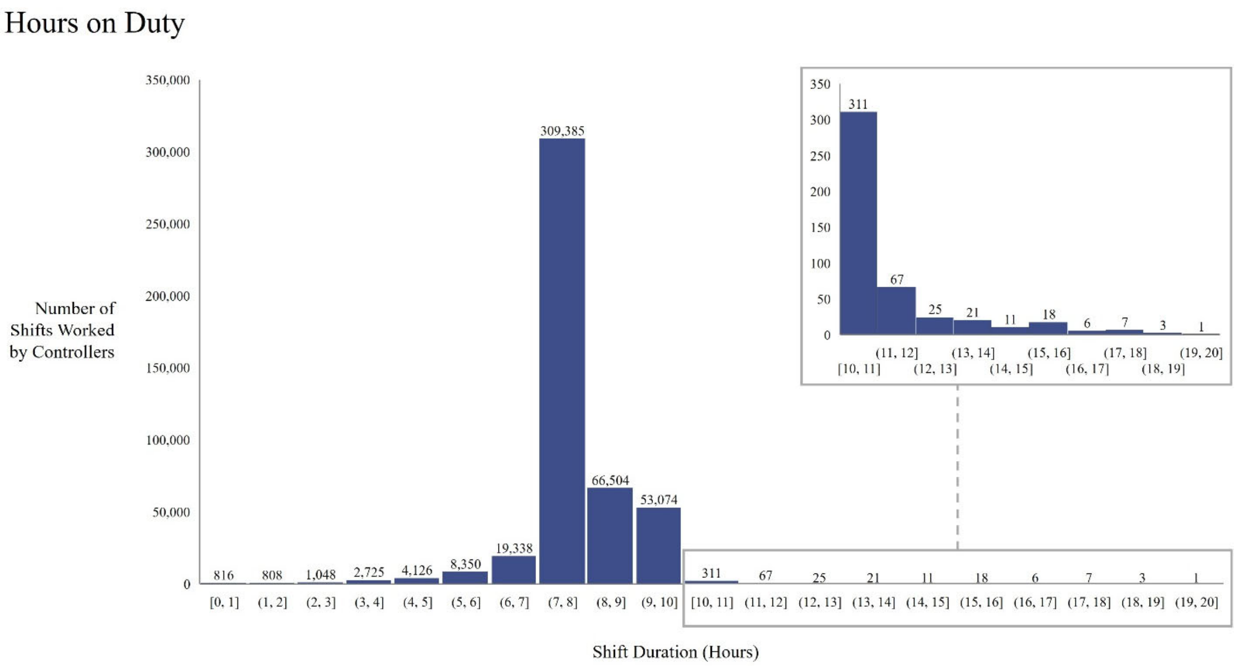


*Figure SP- 4*

During the first 10 weeks of 2024, the average time off interval between operational shifts worked was most commonly between 8 hours and 16 hours in duration. However, 442 shifts began with less than 8 hours off between shifts, including 192 shifts that began with less than 4 hours off between shifts, as shown in Figure SP-5.

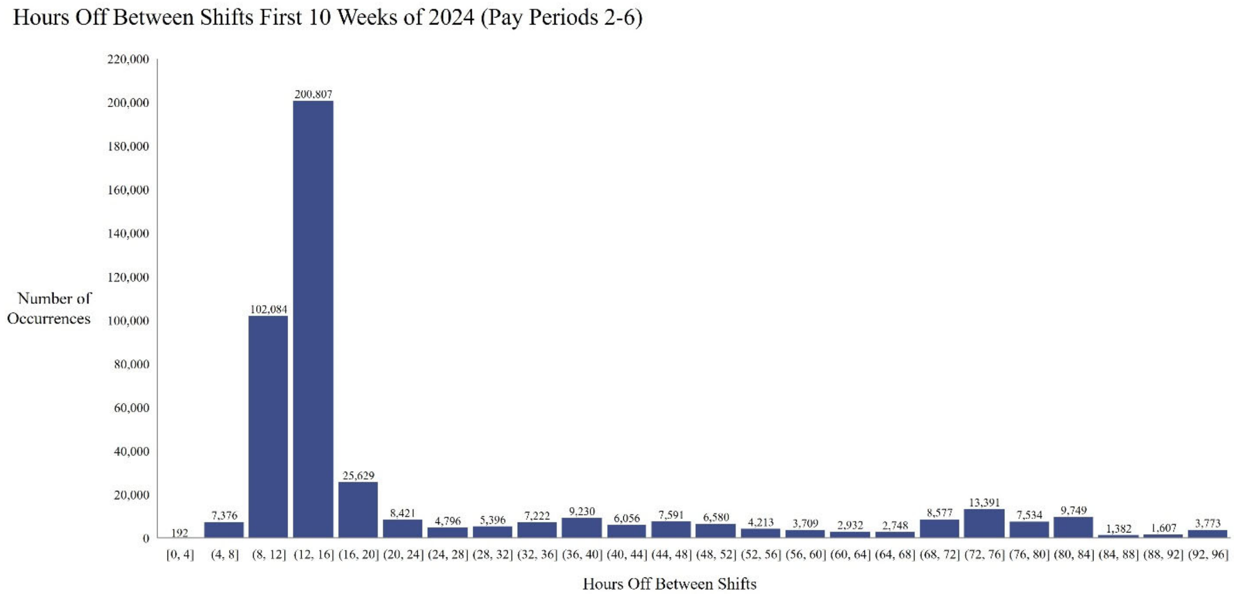


*Figure SP- 5*

From a regulatory perspective, it has been acknowledged for almost 90 years that 8 hours off duty does not provide sufficient time to obtain adequate sleep prior to working during the daytime, and is even more detrimental prior to working the overnight shift. In 1937, when the Interstate Commerce Commission promulgated Hours of Service regulations for commercial motor vehicle drivers operating in interstate commerce it wrote: "*It is obvious that a man cannot work efficiently or be a safe driver if he does not have an opportunity for approximately 8 hours sleep in 24. It is a matter of simple arithmetic that if a man works 16 hours per day he does not have the opportunity to secure 8 hours sleep. Allowance must be made for eating, dressing, getting to and from work, and the enjoyment of the ordinary recreations*" (65 FR 25540).

In the month of January 2024, on the average day, controllers worked an average of 3,418 morning shifts per day, as shown in the Table below.

| SHIFT NAME | TOTAL SHIFTS WORKED | AVERAGE SHIFTS PER DAY |
|---|---|---|
| Early Morning | 844 | 28.1 |
| Morning | 101,709 | 3,390.3 |
| Mid-Day | 11,200 | 373.3 |
| Evening | 73,252 | 2,441.7 |
| Late Evening | 594 | 19.8 |
| Midnight Shift | 21,118 | 703.9 |
| Grand Total | 208,717 | 6,957.2 |

*Table SP- 3*

During the first 10 weeks of 2024, 54,380 morning shifts (99%) began with at least 9 hours off between the prior shift and the start of the morning shift (Figure SP-6). However, 562 morning shifts began with fewer than 9 hours off between the prior shift and the start of the morning shift. *These data would indicate that the "9-hour rule" providing at least 9 hours off between the end of an evening shift and the start of a day shift is not being followed in all circumstances.*

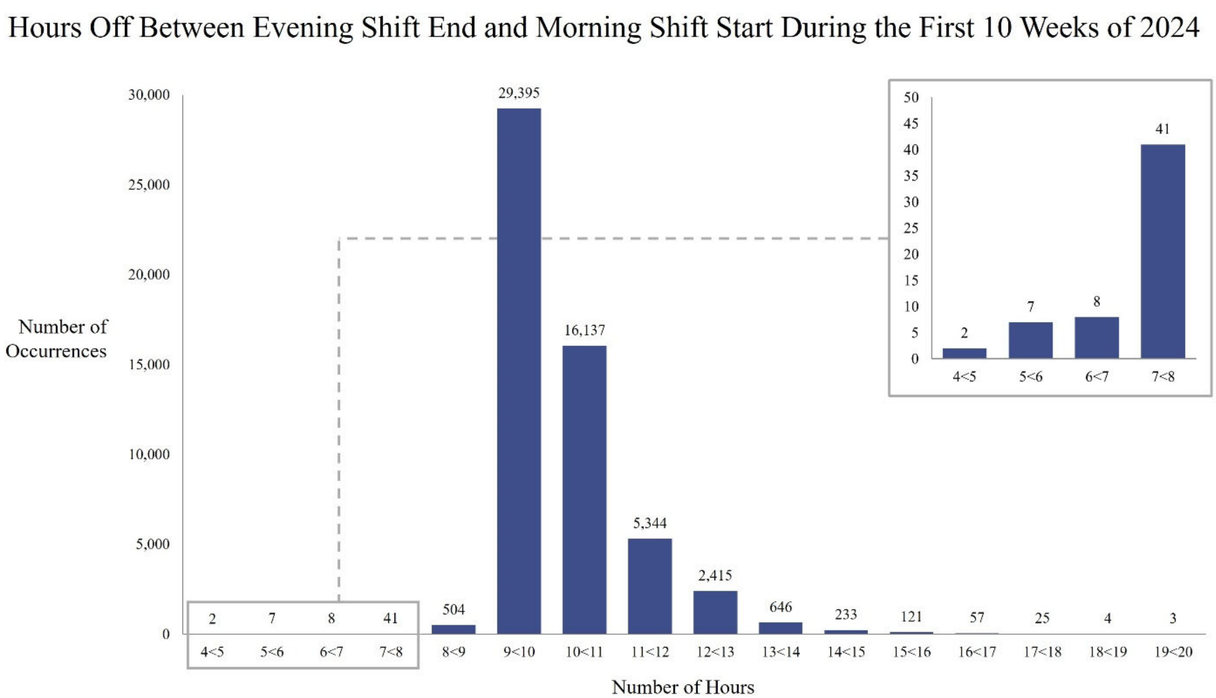


*Figure SP- 6*

For example, in the January 2024 records, a controller worked an evening 10-hour shift that began at 1515 and continued until the next day at 0115. This shift was then followed that same morning with an 8-hour early morning shift that began 5.5 hours later at 0645. During this 6-day interval, the controller worked 6 separate shifts, as illustrated in Figure SP-7.

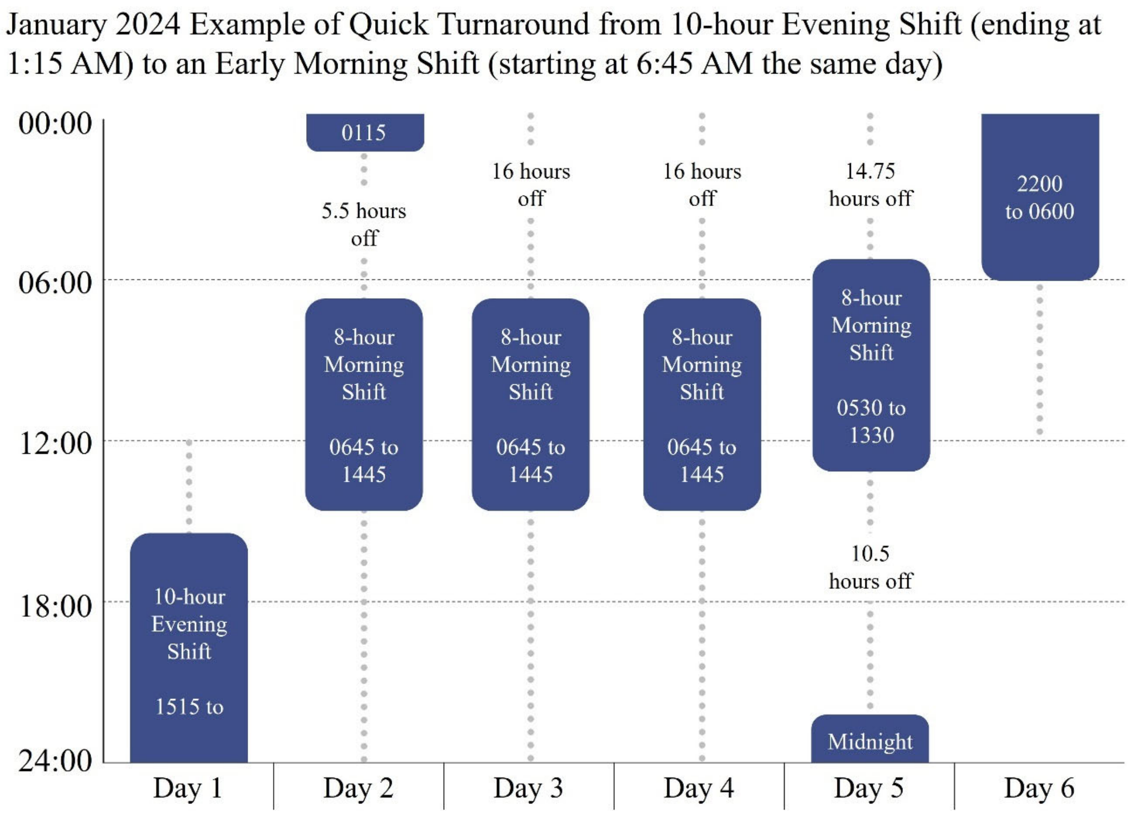


*Figure SP- 7*

In the month of January 2024, controllers worked a total of 21,118 midnight shifts, 14,633 (69.3%) of these began on the same day as the prior day shift had ended. Anecdotally, it was reported that the prior day shift was often started earlier (for example at 0500 or 0600) in order to provide an 8- to 9-hour interval between the end of the day shift and the start of the same-day midnight shift. *Scheduling two shifts in the same 24-hour interval significantly increases controller fatigue risks for performance errors*.

Analysis of the 10-week dataset revealed that 33,463 of these same-day midnight shifts (99.6%) were preceded by at least 8 hours off duty between shifts, and that 148 midnight shifts were preceded by less than 8 hours off duty, as shown in Figure SP-8. *These data would indicate that the intended minimum of 8 hours off duty prior to the start of a midnight shift is not being followed in all circumstances.*

Hour Off Between Morning Shift End and Midnight Shift Begin on the Same Day for First 10 Weeks of 2024 (Pay Periods 2-6)

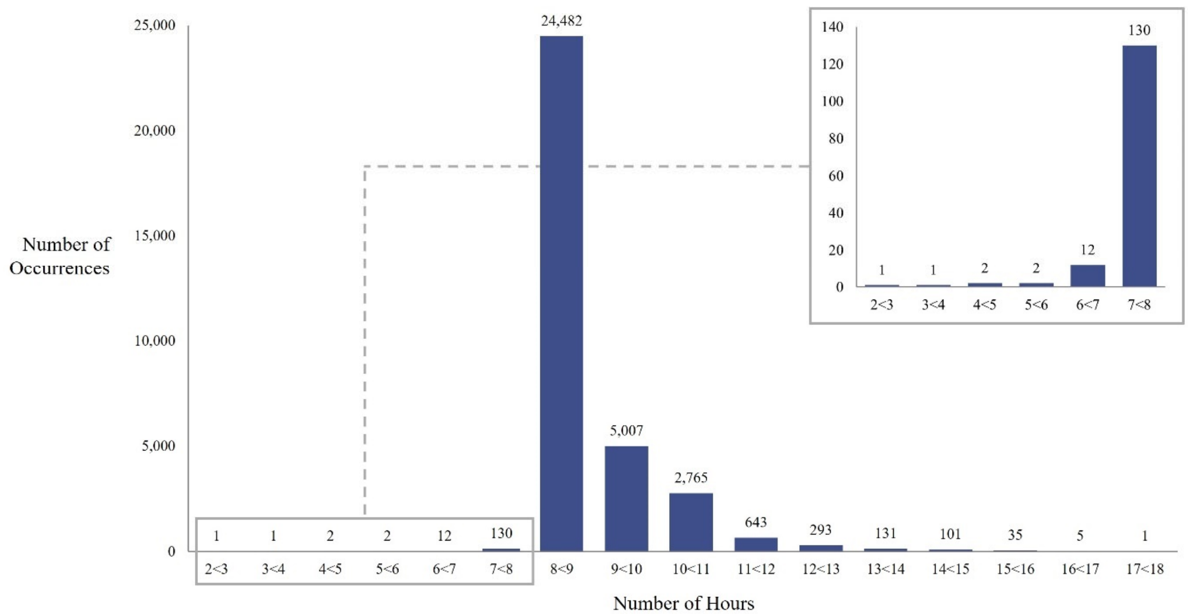


*Figure SP-* 8

As an example, January 2024 records, show a controller worked an early morning 10-hour shift that began at 0530 and continued throughout the day until 1530. Then 6.5 hours later at 2200 that same evening, it was followed by an 8-hour midnight shift. This midnight shift continued on the same date that the controller finished the day shift and continued until 0600 the following morning (Figure SP-9).

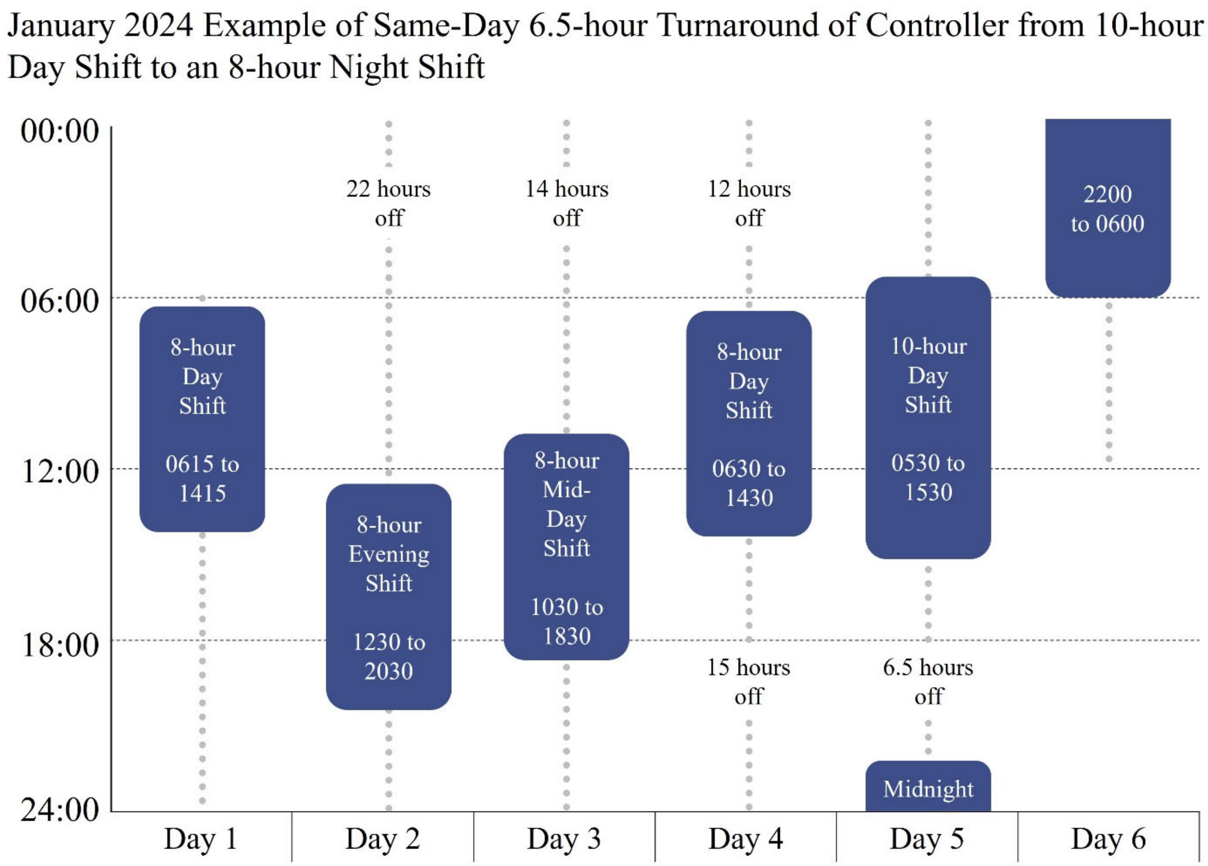


*Figure SP- 9*

The following figures provide examples of excessive overtime. There were four controllers who worked 30 or more consecutive days in January 2024 (Figures SP-10, SP-11, SP-12 and SP-13), and one of these controllers worked all 70 calendar days during the first 10 weeks of 2024 (SP-13). Two of these controllers worked very irregular work schedules (SP-10 and SP-11), whereas the other two controllers worked almost entirely midnight shifts (SP-12 and SP-13). These four controllers logged overtime hours that totaled 9, 9, 20 and 10 days for the month of January (Figures SP-10, SP-11, SP-12 and SP-13), and 11 days for the first 10 weeks of 2024 (Figure SP-13) (as coded by "RDO+OT" or "OT+Regular"). *These schedules are allowable under the current policies but represent opportunities to apply sleep, circadian, and fatigue science to reduce controller fatigue risks.*

Data from work shifts and time off of work are double plotted in a raster format, with successive days plotted both next to and beneath each other. Hours are along the horizontal axis and days down the vertical axis; 2 days are plotted across each horizontal line. Work shifts are represented by the solid black bars, while the thin horizontal black lines represent time off from work. X-axis displays clock hour beginning at midnight, with the vertical hatched lines marking every six hours. Y-axis displays consecutive days, with each day presented beneath the previous day.

In Figure SP-10, the controller is scheduled to work shifts every calendar day of January 2024. Those work shifts are occurring at progressively earlier clock times throughout the month, advancing about 3.43 hours earlier each day and thereby forcing this controller to work a non-24-hour schedule, effectively a 20.6-hour "day." Numerous laboratory and field studies have demonstrated that such a schedule induces desynchrony between the timing of the individual's endogenous (internal) circadian rhythms and the timing of the work schedule,[26-28] as used to occur among submariners scheduled to an 18-hour watch schedule. *Such forced desynchrony between the work-rest schedule and endogenous circadian rhythms degrades cognitive and neurobehavioral performance, impairs learning[29-32] and increases the probability of attentional failures while on shift. Moreover, chronic exposure to recurrent circadian disruption induces adverse health consequences.[33-35]* During this month, the controller whose schedule is illustrated in Figure SP-10 worked 9 overtime shifts.

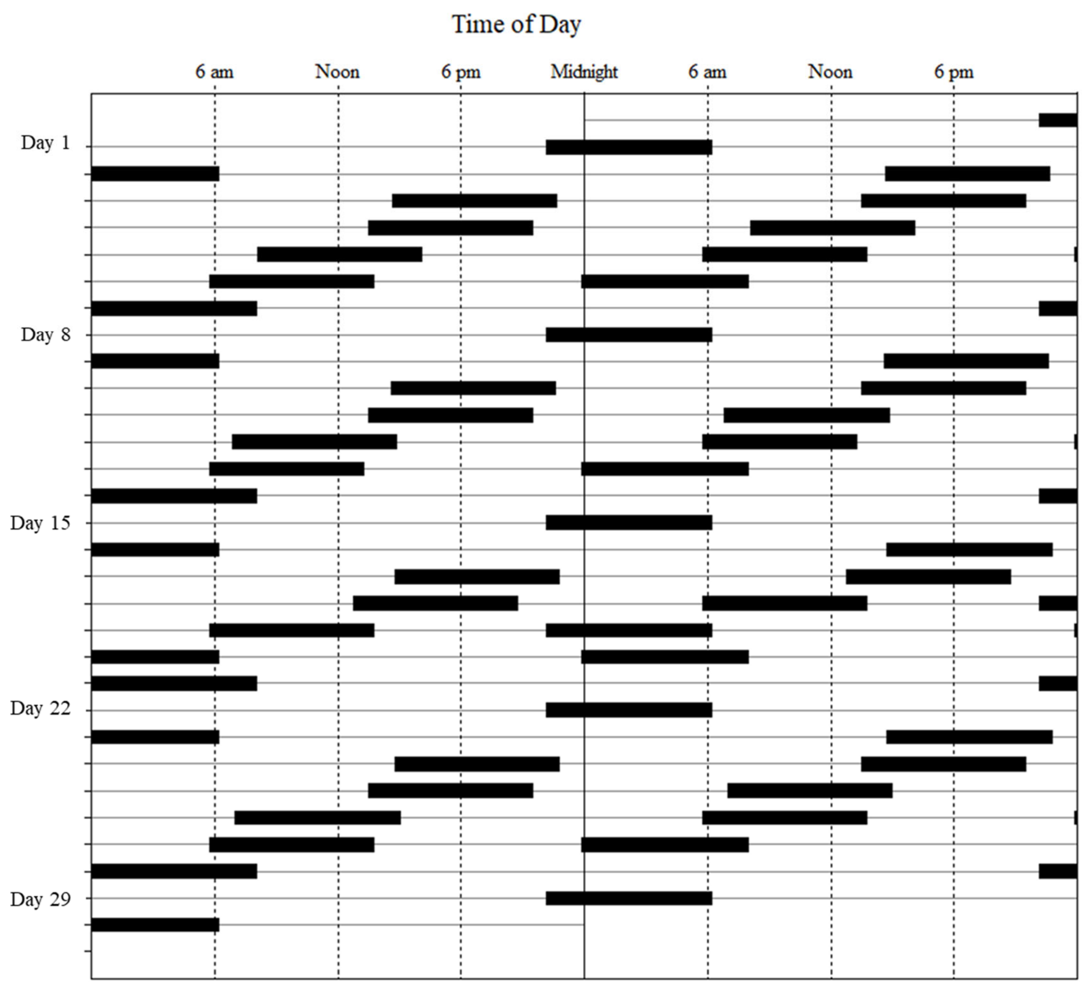


*Figure SP- 10*

In Figure SP-11, the controller was scheduled to work shifts every calendar day January 2024. For 10 days, in January 2024, those work shifts were occurring at very irregular times. For the rest of the month, this controller was working mostly night shifts. During this month, the controller schedule illustrated in Figure SP-11 worked 9 overtime shifts.

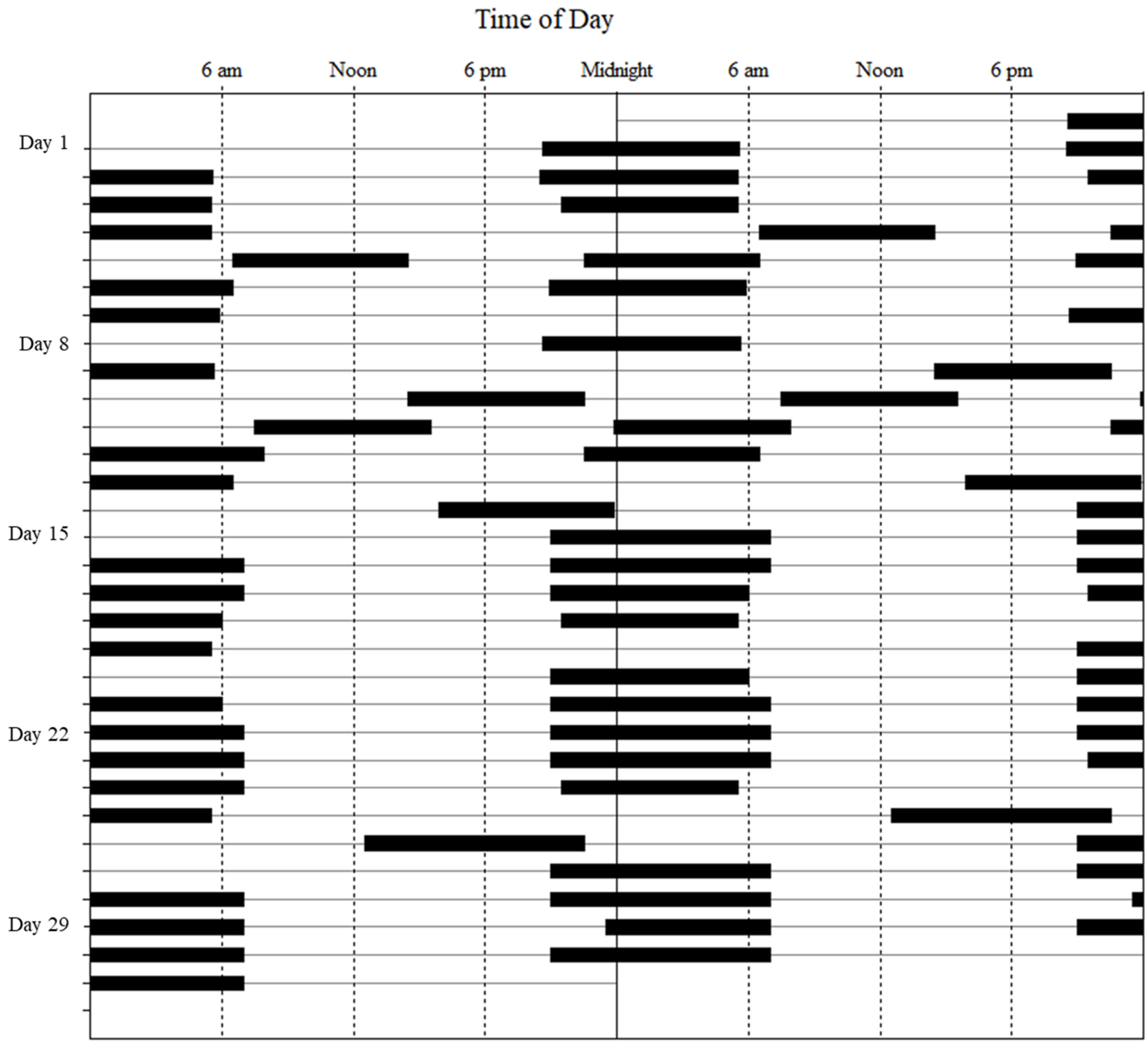


*Figure SP- 11*

Figure SP-12 illustrates the work schedule of a controller scheduled to work shifts every calendar day of January 2024; this included night shifts on 22 out of the controller's 24 shifts. During this month, the controller schedule illustrated in Figure SP-12 worked 20 overtime shifts.

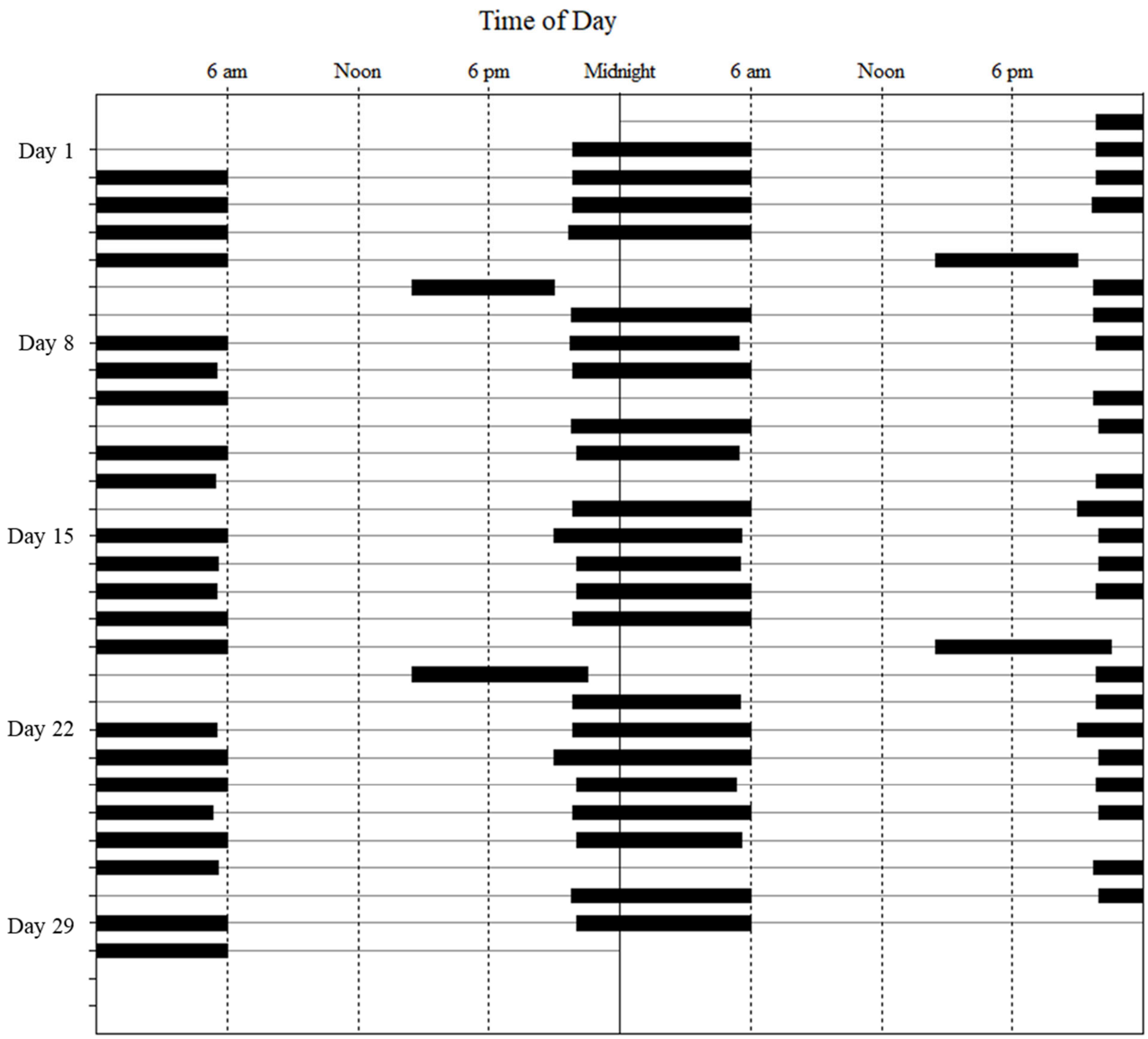


*Figure SP- 12*

Figure SP-13 illustrates the work schedule of a controller scheduled to work shifts every calendar day during the first 10 weeks (70 days) of 2024; all but one of these work shifts was a night shift. During this 10-week interval, the controller schedule illustrated in Figure SP-13 worked 11 overtime shifts.

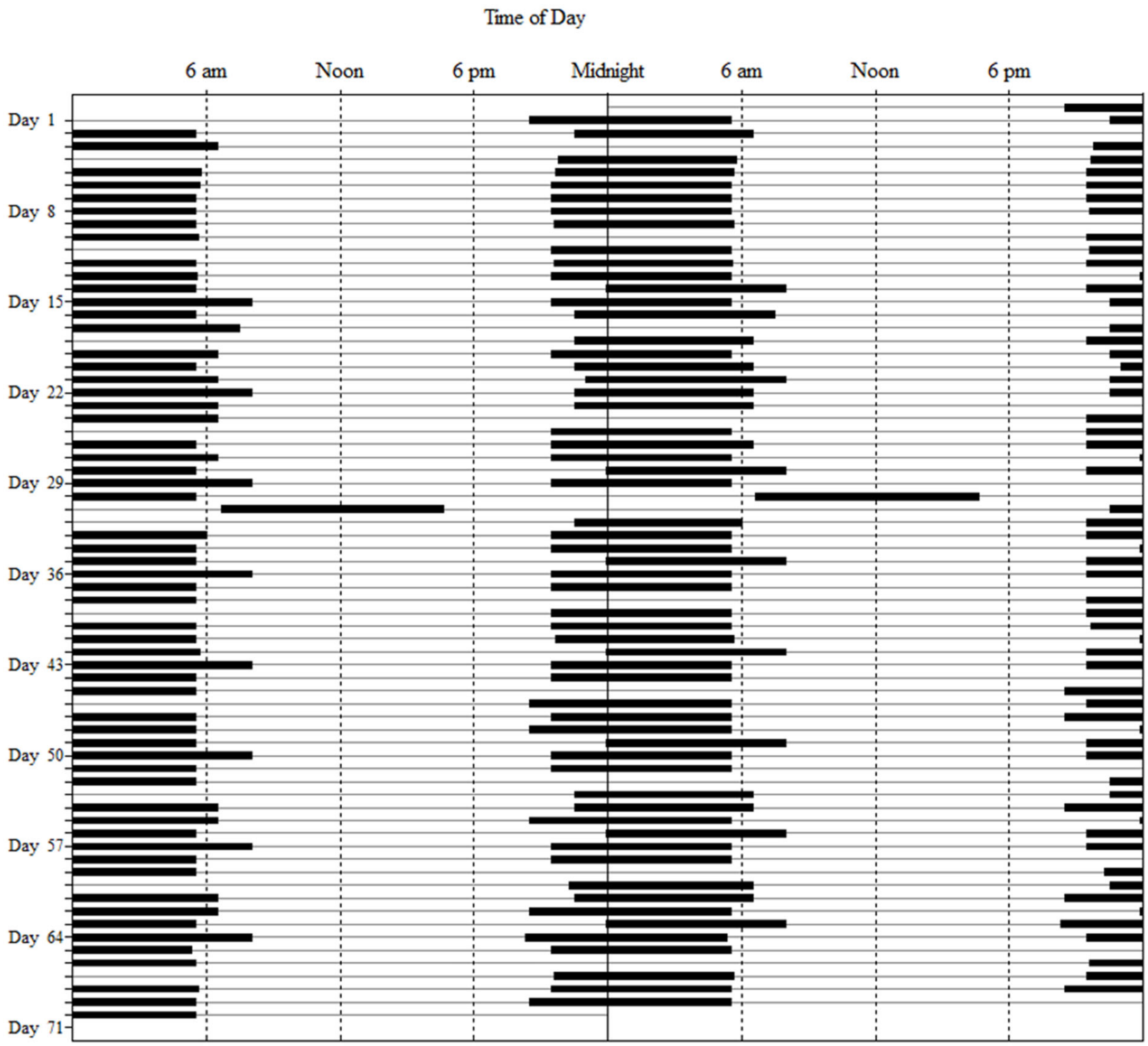


*Figure SP- 13*

The analysis of the first 10 weeks of 2024 examining consecutive days worked by controllers is portrayed in Figure SP-14. The majority of sequences worked by controllers (80.2%) involved 5 or fewer consecutive work days. However, 20,766 sequences (18.2%) involved 6 consecutive work days and 1,793 sequences involved seven or more (range 7 to 70) consecutive calendar days worked. *It will be important to conduct a more detailed examination of these practices in a larger dataset because working six or seven days in a row could increase controller fatigue risk, especially when insufficient recovery time is provided following significant overtime periods*

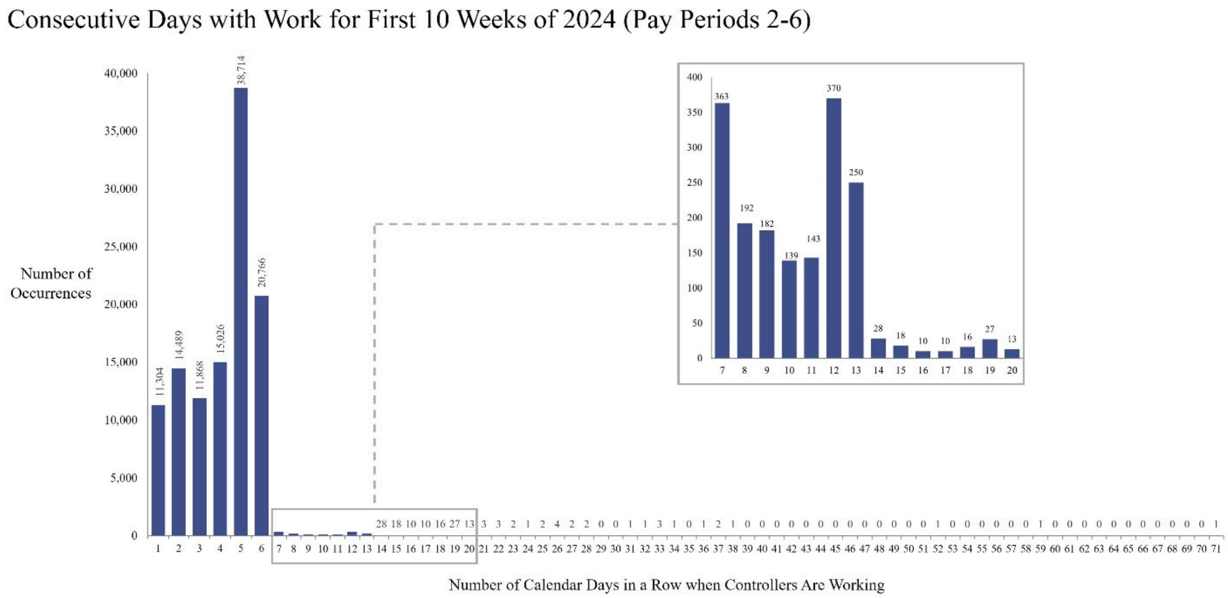


*Figure SP- 14*

Figure SP-15 portrays the number of consecutive midnight shifts worked by controllers in the first 10 weeks of 2024. There were 33,473 midnight shifts that were single shifts, consistent with the counterclockwise rotating 2-2-1 schedule commonly worked by controllers. However, 564 occurrences involved sequences of 5 or more consecutive night shifts.

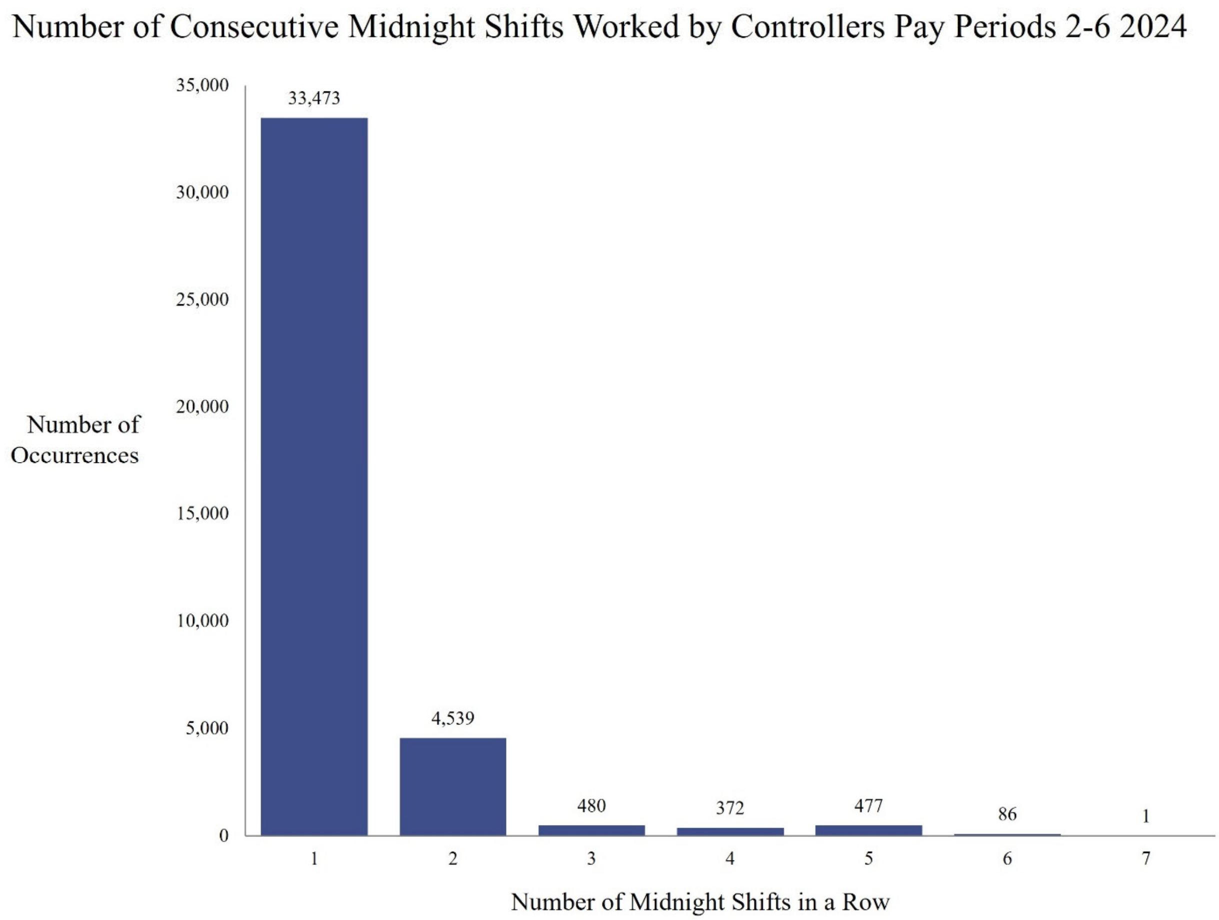


*Figure SP- 15*

Although there is a 10-hour limit on the duration of shifts for controllers conducting operational duties, there is no limit on the duration of shifts involving non-operational duties. Moreover, analysis of the data revealed that some controllers work shifts separated only by brief intervals off duty, such that neither shift exceeded 10 hours, but taken together they could exceed 10 hours. *Extended hours of continuous wakefulness is a known fatigue risk than can increase performance errors. These situations should be identified, monitored, and prevented.*

Currently, 14CFR§65.47 Maximum hours provides the following: " . . . an operator may not serve or be required to serve . . .  b) For more than 10 hours during a period of 24 consecutive hours, unless he has had a rest period of at least 8 hours at or before the end of the 10 hours of duty. Figure SP-16 shows the schedule of a controller working with apparently only a 50-minute break between 8-hour shifts. *As noted, extended hours of continuous wakefulness is a known fatigue risk than can increase performance errors. These situations should be identified, monitored, and prevented.*

March 2024 Example of Controller with only a 50-minute Break between Two 8-hour Shifts

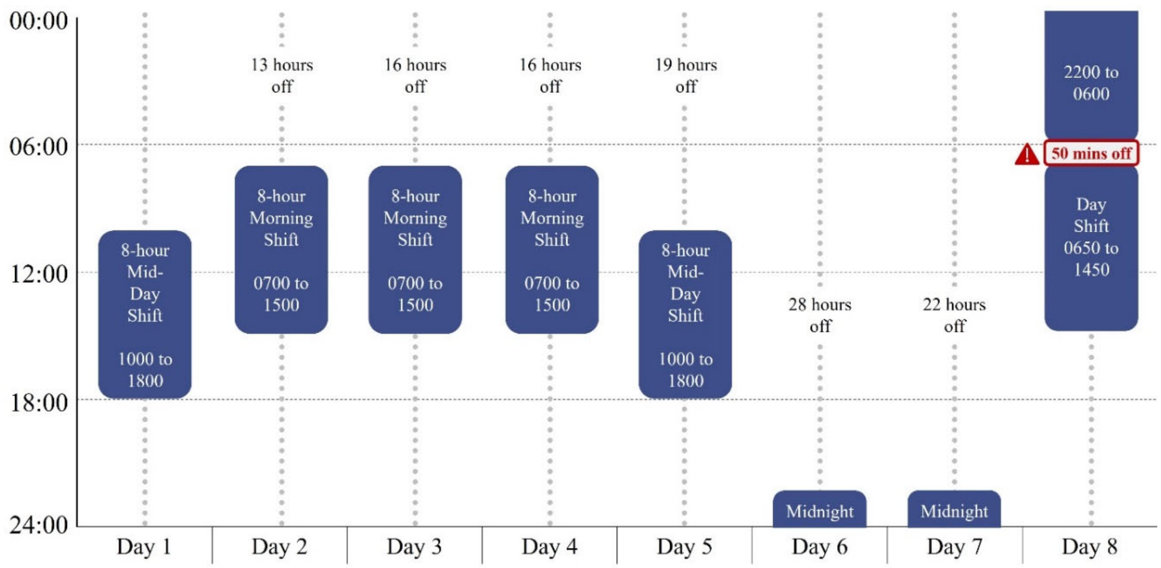


*Figure SP- 16*

Figure SP-17 illustrates the schedule of a controller who apparently had only a 4.1 hours off-duty period between a 15.2 hour and a 6.25-hour shift (Day 3). *Clearly, insufficient off-duty periods will result in acute loss sleep, a known fatigue risk than can increase performance errors. These situations should be identified, monitored, and prevented.*

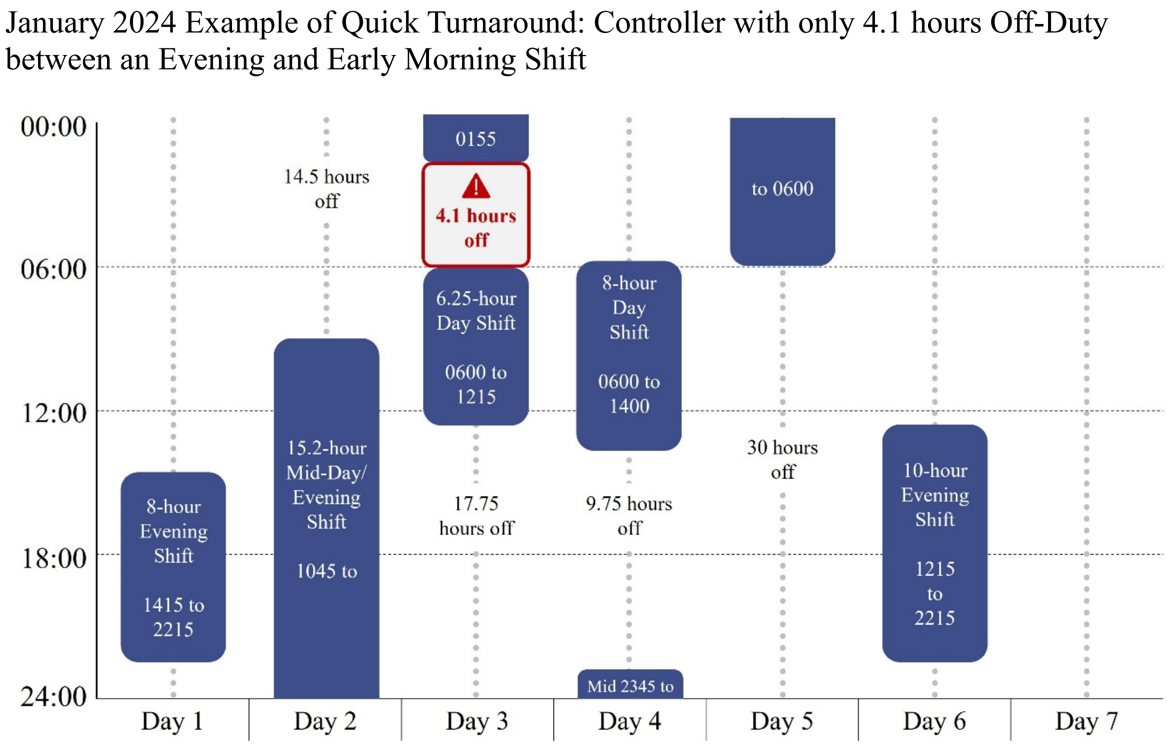


*Figure SP- 17*

### *Strengths*

The six core features (p.43) known to address sleep, circadian, and fatigue factors in scheduling practices provide an opportunity to incorporate research findings and operational experience in efforts to address and minimize or mitigate fatigue risks in controller schedules. In an effort to examine and characterize some common, current ATO scheduling features, FAA data from 747,177 individual reports of work hours and days off recorded during the first 10 weeks of 2024 (December 31, 2023 to March 9, 2024, during Pay Periods 2 through 6) from 10,363 controllers with operational duties were analyzed. These data provide some insights to average total hours worked, hours on duty, hours off between shifts, hours between end of the evening shift and start of the morning shift, hours between end of the day shift and same-day start of the midnight shift, consecutive days of work, and consecutive midnight shifts. Even though the scheduling is handled locally, and there are hundreds of minor variations, these data reveal that there are commonalities across facilities. *Also, it confirms that a majority of controllers work within existing scheduling policies and agreements. It also shows that a majority of controllers continue to work the counterclockwise rotating 2-2-1 schedule when working a single midnight shift.*

*Risks*

While the data presented do provide insights, as already identified, there are limits to the current dataset, such that the results can *not* be generalized beyond the exploratory nature of this analysis. Also, while these data may describe 'what' happened, they do not explain the 'why' of any specific circumstance and therefore interpretation is limited.

For the scheduling factors examined, there were multiple instances where results showed that planned policy or agreement limits had been exceeded. Clearly, the circumstances surrounding these exceedances require further examination to understand the specifics of these situations so they can be addressed. While no particular error, incident or accident is known to be associated with these exceedances, they represent significant fatigue risks in the system. One common explanation for some circumstance exceedances was whether the shift involved "operational" or "non-operational" (ancillary or administrative) duties. It was acknowledged that operational duties had more direct safety implications if fatigue-related performance decrements emerged. However, non-operational duties can still increase continuous hours of wakefulness (a potential fatigue risk factor) and reduce performance on training and other ancillary duties that may have subsequent safety consequences.

The counterclockwise rotating 2-2-1 schedule continues to be operated by the majority of controllers working a single midnight shift. A decade ago, a TRB report[36] addressed this schedule:

> "Rare but highly publicized incidents of controllers falling asleep on the job have drawn attention to the risks associated with controller fatigue. As a result of these incidents, night shifts with a single controller on duty are no longer permitted in most circumstances. Other prescriptive limitations on controllers' work schedules and duty times, such as mandatory breaks and lunch periods and limits on the number of hours worked in a shift, aim to mitigate the risks associated with controller fatigue. Another result was the 9-hour rule, which requires controllers to have a minimum of 9 hours off duty preceding the start of a day shift. The intention of such actions is to improve safety by increasing controllers' opportunities for nighttime sleep.
>
> Despite recent policy changes such as the 9-hour rule and efforts to educate controllers about fatigue issues through a series of fatigue risk management bulletins, some controller schedules continue to raise concerns about fatigue. In particular, the counterclockwise rotating 2-2-1 schedule … compresses the workweek and then allows controllers 80 hours off. Although the schedule … is popular among controllers, it results in severely reduced cognitive performance during the midnight shift because of fatigue."

The counterclockwise rotating 2-2-1 schedule creates known fatigue risks in air traffic controller operations, has been specifically identified by a range of experts, reports, and ATO surveys for creating these risks, and yet continues to be worked by a majority of controllers working a single midnight shift.

There are structured methods to examine fatigue factors in transportation accident investigations used by the NTSB and others[37, 38] Applying these methods to current ATO schedules and data provided throughout this report suggest that a variety of fatigue risk factors, such as acute sleep loss, cumulative sleep debt, continuous hours of wakefulness, and multiple circadian disruption variables would be identified.

The NTSB has made recommendations related to air traffic controller fatigue, including from the 2006 Comair accident investigation[39] though fatigue was not identified as a finding or causal. These NTSB recommendations included one to the FAA and the same one to NATCA: "Work with the [National Air Traffic Controllers Association/Federal Aviation Administration] 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."
(A-07-32)

Cited in NTSB investigations and safety recommendations are several instances that highlight fatigue risks associated with controller schedules. Some examples: 1) Chicago O'Hare International Airport (ORD) Runway Incursion [40] 2) Los Angeles International Airport (LAX) Runway Incursion [41] 3) Denver International Airport Refueling Accident [42] 4) King County International Airport - Boeing Field Runway Incursion. [43] These examples illustrate the sleep, circadian, and fatigue risks that have been identified in previous NTSB investigations.

### *Biological Needs Opportunities (BNO)*

*BNO1.* Conduct a thorough examination of the six core scheduling features identified (p.43) using recent and current FAA data to characterize the present state of scheduling practices, including planned vs. actual work schedules.

*BNO2. Identify and determine specific circumstances around a subset of representative scheduling policy and agreement exceedances then implement mechanisms to monitor and eliminate such exceedances. This effort should be focused on developing and implementing these mechanisms and not involve punitive actions for past circumstances.* ***(Priority Opportunity)***

*BNO3. Develop and implement a strategy to eliminate the counterclockwise rotating 2-2-1 schedule and replace it with a schedule design that addresses operational requirements and incorporates sleep and circadian principles.* ***(Priority Opportunity)***

*BNO4. Develop and implement a strategy to update the current prescriptive policies to address identified fatigue factors, especially to avoid known schedule practices that induce fatigue. Specifically, require sufficient time off-duty (e.g., 10-12 hours) before all shifts, whether controllers are performing operational or non-operational tasks. Also, this off-duty time should account for the circadian timing of the shift, where increased off-duty time may be required before midnight shifts.* ***(Priority Opportunity)***

*BNO5.* Establish mechanisms to track planned vs. actual schedules worked, including time dedicated to ancillary duties. Monitor and address policy and agreement exceedances, and evaluate the effectiveness of scheduling practice changes. Use these mechanisms for regular evaluation of fatigue risks and to implement ongoing enhancements to address sleep, circadian, and fatigue factors in air traffic controller operations.

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# Conclusions

At the request of the FAA Administrator, a Scientific Expert Panel on Air Traffic Controller Safety, Work Hours, and Health evaluated the FAA's current air traffic controller workforce, work requirements, and scheduling practices as they relate to the latest science on human sleep and circadian needs and fatigue considerations. "The purpose of this evaluation is to inform FAA's ongoing efforts to enhance the safety and well-being of the agency's controller workforce and the safety of the aviation system." Within the three areas identified by the FAA, the Scientific Expert Panel on Air Traffic Controller Safety, Work Hours, and Health further defined these 11 topic areas: 1) workforce - staffing, prescriptive policies/regulations and fatigue risk management, health, and other factors; 2) work requirements – cognitive demands, workload, controller staffing utilization, and work environment; and 3) scheduling practices – operational requirements, employee needs and preferences, and biological needs.

The approach used by the Scientific Expert Panel was to identify the strengths, risks, and opportunities within each of the 11 topics. The identified strengths provide assets and successes to be continued and wherever possible enhanced and expanded. The identified risks create individual and system vulnerabilities that can result in safety, performance, health, and mood decrements. These risks have the potential to introduce errors, incidents, and accidents that are related to known and scientifically well-established fatigue factors. Addressing these vulnerabilities will reduce or mitigate fatigue risks. By identifying opportunities to enhance strengths and address fatigue risks, the FAA, and relevant stakeholders such as NATCA, can pursue actions informed by their expertise and the realities of everyday operational demands, staffing, and funding. Many of these opportunities could be enacted without increasing controller staffing levels. The Scientific Expert Panel identified a large, broad set of 58 opportunities for the FAA and others to consider and pursue in their efforts to address fatigue risks within ATO.

Based on the findings of this evaluation and the 58 opportunities identified, the Scientific Expert Panel strongly recommends that the FAA form a working group to evaluate and determine next steps. The working group can have three subgroups (workforce, work requirements, and scheduling practices) and would serve to coordinate and facilitate the overall program of actions and ensure activities are integrated, complementary, and not redundant. Each subgroup could evaluate relevant opportunities and develop a strategic plan for each topic that includes specific objectives, near- and long-term plans, milestones, timelines, and resources. It will be critical to include evaluation plans to ensure that objectives are met and fatigue risks are actually reduced or mitigated. This also allows the FAA, and relevant stakeholders such as NATCA, to ensure that their subject matter expertise regarding ATO drives their actions, informed and guided by the sleep, circadian, and fatigue science available.

While the FAA will determine its specific objectives, actions, priorities, and timelines, given the 58 total opportunities identified, the Scientific Expert Panel strongly urges the FAA to quickly initiate action on the following four opportunities:

*PPR/FRMO1.* Integrate prescriptive policies/regulations and FRMS into an appropriately structured single system that provides one source for FAA ATO FRM activities. This should include a single source repository of all relevant materials, ensuring consistency across elements, and emphasizing the integrated and complementary elements of the system.

*BNO2.* Identify and determine specific circumstances around a subset of representative scheduling policy and agreement exceedances then implement mechanisms to monitor and eliminate such exceedances. This effort should be focused on developing and implementing these mechanisms and not involve punitive actions for past circumstances.

*BNO3.* Develop and implement a strategy to eliminate the counterclockwise rotating 2-2-1 schedule and replace it with a schedule design that meets operational requirements and that incorporates sleep and circadian principles.

BNO4. Develop and implement a strategy to update the current prescriptive policies to address identified fatigue factors, especially to avoid known schedule practices that induce fatigue. Specifically, require sufficient time off-duty (e.g., 10-12 hours) before all shifts, whether controllers are performing operational or non-operational tasks. Also, this off-duty time should account for the circadian timing of the shift, where increased off-duty time may be required before midnight shifts.

These 11 opportunities should be the next near-term actions areas:

### Workforce

*SO1.* Establish a unified, data-based model for air traffic staffing requirements then enact changes with clear near- and long-term activities, milestones, annual evaluation, and adjustments as needed. Reflect SRT recommendations regarding staffing and funding.

*SO4.* Analyze work requirements and scheduling practices opportunities identified in this report to determine potential changes that will affect staffing needs at the system and individual facility level. Integrate identified changes into staffing models, develop a deployment strategy, and ensure plans account for near- and long-term actions.

*PPR/FRMO2.* Review/evaluate each specific element of fatigue-related policies, regulations, CBA, and MOUs to determine if they meet explicit FAA FRM objectives, including their operational relevance and basis in known sleep, circadian, and fatigue science. Pursue identified gaps and changes to ensure optimal benefits, including new approaches.

### Work Requirements

*CDO1.* Re-assess controller time on position limits to determine whether a shorter or longer duration is appropriate given current technology, traffic levels, environmental factors, and time of day. Determine whether a fixed time on position limit (i.e., nominally two hours) is appropriate for all types of air traffic facilities, regions, and time of day. This could be done through a dedicated study or possibly by using existing data from air traffic facilities.

*WO1.* Maintain and enhance the MAP tool or replace it with a tool (existing or through development) that provides real-time traffic forecasting.

*CSUO7.* Provide explicit FRM education and guidance on how to maximize the benefits of recuperative rest breaks.

*WEO1.* Identify, test, and deploy a standardized lighting level that allows for optimal alerting, while also assuring lighting is appropriate to meet task needs.

## Scheduling Practices

*ORO1.* Identify and use mechanisms to ensure that known sleep and circadian science as well as FAA/CAMI and other relevant research findings are used to provide input and guide policy, CBA, MOUs, and other scheduling practice efforts. These could include individuals, reports, briefings, etc. that are integrated into working groups or other mechanisms used to address scheduling practices and fatigue management.

*ORO4*. Within an appropriately short timeframe, develop a strategic plan and explicit tactical milestones to determine and deploy a scheduling tool or resource to support facility supervisors' scheduling practices. Incorporate a relevant fatigue risk modeling tool into the scheduling tool or as a component of scheduling procedures. Evaluate the scheduling tool and fatigue risk modeling predictions on a regular basis to ensure optimal effectiveness and value.

*ENPO1.* Given that most of the data regarding scheduling preferences are about 25 years old, quickly conduct focused surveys to update this information and expand questions to reflect current circumstances and specific schedule features.

*BNO1.* Conduct a thorough examination of the six core scheduling features identified (p.43) using recent and current FAA data to characterize the present state of scheduling practices, including planned vs. actual work schedules.

These specific 15 opportunities provide a foundational starting point for critical near-term actions in all three evaluation areas: workforce, work requirements, and scheduling practices. And there are 43 more opportunities that need attention and action in a timely manner.

Given the dynamic complexity of the safety-sensitive demands of air traffic operations, and the major systems that have evolved over decades to meet these requirements, it should be clear that there is no simple or single solution that will eliminate fatigue risks. In fact, there can be significant barriers, including inertia and comfort with what is known, that can slow or impede progress. Noted throughout this report are fatigue risks that have existed in ATO for decades related to workforce, work requirements, and scheduling practices. Without action, these risks will continue to grow and become more severe over time with individual and system cumulative effects.

The effects of staffing levels on fatigue risks have been discussed throughout this report. Obviously, once staffing levels are increased to an appropriate level to meet operational demands, some of these identified fatigue risk-related opportunities will need to be revisited. For example, fatigue risk factors related to overtime, consecutive days or weeks worked, and mechanisms to address variable traffic/workload scenarios could be improved or potentially eliminated with appropriately increased staffing levels.

However, even optimal staffing does not eliminate the inherent biological fatigue risks that exist in any around-the-clock operational setting. Sleep loss and circadian disruption created by night work and rotating shifts engender known safety and performance decrements that can lead to errors, incidents, and accidents.

Implementing scheduling changes can be very difficult, resource intensive, and require considerable time. The FAA and other stakeholders (e.g., NATCA) will have to consider operational demands, staffing, funding, and many other factors when pursuing the opportunities identified in this report.

This report is intended to provide a tool for the FAA to pursue actions that address the identified strengths and risks in air traffic operations. There are many strengths identified that the FAA can build upon and identified vulnerabilities that can be addressed through sustained efforts to minimize or mitigate fatigue risks. As envisioned, this report can “inform FAA’s ongoing efforts to enhance the safety and well-being of the agency’s controller workforce and the safety of the aviation system.”

## Summary of Opportunities (58)

### Staffing Opportunities (SO)

*SO1.* Establish a unified, data-based model for air traffic staffing requirements then enact changes with clear near- and long-term activities, milestones, annual evaluation, and adjustments as needed. Reflect SRT recommendations regarding staffing and funding.

*SO2.* Review available ATC task analysis and workload data to determine the current state of knowledge and gaps specifically as related to sleep, circadian, and fatigue factors, then update staffing models, including with new research findings. Conduct regular reviews to maintain currency of data to reflect ATC operational tasks, demands, workload, and fatigue risks especially in the context of changing technologies.

*SO3.* Continue, and where appropriate extend, data collection on overtime (mandatory and voluntary), extended consecutive work periods (days, weeks, months), merging positions, and supervisory roles (oversight vs. operational) then ensure findings are reflected in staffing requirements and scheduling practices to minimize fatigue effects and risks.

*SO4.* Analyze work requirements and scheduling practices opportunities identified in this report to determine potential changes that will affect staffing needs at the system and individual facility level. Integrate identified changes into staffing models, develop a deployment strategy, and ensure plans account for near- and long-term actions.

### Prescriptive Policies/Regulations and Fatigue Risk Management Opportunities (PPR/FRMO)

*PPR/FRMO1.* Integrate prescriptive policies/regulations and FRMS into an appropriately structured single system that provides one source for FAA ATO FRM activities. This should include a single source repository of all relevant materials, ensuring consistency across elements, and emphasizing the integrated and complementary elements of the system.

*PPR/FRMO2.* Review/evaluate each specific element of fatigue-related policies, regulations, CBA, and MOUs to determine if they meet explicit FAA FRM objectives, including their operational relevance and basis in known sleep, circadian, and fatigue science. Pursue identified gaps and changes to ensure optimal benefits, including new approaches.

*PPR/FRMO3.* Evaluate existing, relevant CAMI fatigue research to identify opportunities for application across FRM activities. Pursue and apply/translate relevant findings into operational practice where appropriate.

*PPR/FRMO4.* Develop a strategic plan for CAMI fatigue-related research, including air traffic-related projects, that includes reactive and proactive activities. Identify explicit operational outcomes to be addressed when research findings become available.

*PPR/FRMO5.* Develop and implement a communication plan that transfers relevant CAMI findings to appropriate internal FAA groups in an ongoing manner.

*PPR/FRMO6.* Organize a small annual external advisory group meeting to review the CAMI ATC fatigue-related strategic plan, research projects, findings, application opportunities, and to help identify potential future research. The advisory group should include relevant stakeholders as well as subject matter experts.

*PPR/FRMO7.* Review/evaluate FRMS activities to determine if they meet explicit FAA FRM objectives, including their operational relevance and basis in known sleep, circadian, and fatigue science. Pursue identified gaps and changes to ensure optimal benefits, including new approaches.

*PPR/FRMO8.* Review current plans for revising ATSAP activities, form, etc. to ensure that any new efforts will enhance reporting and especially the use and value of reports/data.

*PPR/FRMO9.* Identify opportunities to apply available FRM activities/products beyond current use. Pursue and apply/translate relevant activities/products into operational practice where appropriate.

*PPR/FRMO10.* Determine appropriate resource needs for effective FRMS activities, including number of personnel, funding, etc.

*PPR/FRMO11.* Organize a small annual external advisory group meeting to review FRMS activities, expected outcomes, application opportunities, program effectiveness, and to help identify potential future projects. The advisory group should include relevant stakeholders as well as subject matter experts.

*PPR/FRMO12.* Identify and employ a reporting structure that ensures relevant FAA leadership (e.g., Administrator, Deputy Administrator, ATO leaders, other safety stakeholders such as NATCA) remain informed on a regular basis (e.g., quarterly) through multiple mechanisms (e.g., briefings, written materials) about ongoing, planned, and timely occurrences of ATC fatigue activities, issues, effectiveness, and plans.

## Health Opportunities (HO)

*HO1.* Enhance efforts through multiple mechanisms to provide education, guidance, and resources to understand and access the sleep disorders diagnosis and treatment process, including accredited evaluation centers. Pursue new information mechanisms for implementation. Ensure that provided health insurance programs cover sleep disorders diagnosis and treatment.

*HO2.* Evaluate data sources to examine whether current sleep disorders diagnosis and treatment rates approximate expected prevalence rates.

*HO3.* Ensure that current efforts to understand and address mental health issues in aviation include the air traffic controller population and reflects relevant information and actions related to sleep, circadian factors, and sleep disorders.

### Other Factors Opportunities (OFO)

*OFO1.* Examine the cumulative/long term effects, recovery time off, and age considerations in previous (where available), current, and future air traffic controller research projects. Create a database to accumulate relevant findings from research and pursue opportunities to translate them into operational use. Leverage CAMI expertise, resources, and data whenever possible.

*OFO2.* Construct and pursue a budget to effectively support ATO fatigue activities throughout the FAA to include at a minimum, people, programs, and research.

### Cognitive Demands Opportunities (CDO)

*CDO1.* Re-assess controller time on position limits to determine whether a shorter or longer duration is appropriate given current technology, traffic levels, environmental factors, and time of day. Determine whether a fixed time on position limit (i.e., nominally two hours) is appropriate for all types of air traffic facilities, regions, and time of day. This could be done through a dedicated study or possibly by using existing data from air traffic facilities.

*CDO2.* Identify and implement procedures that allow controllers to acknowledge the handoff of an aircraft during the midnight shift that do not further increase workload.

*CDO3.* Develop specific procedures, decision aids, or tools to assist controllers during infrequent, critical operations.

*CDO4.* Identify ways to expeditiously deploy controller-assist tools across all air traffic facilities.

### Workload Opportunities (WO)

*WO1.* Maintain and enhance the MAP tool or replace it with a tool (existing or through development) that provides real-time traffic forecasting.

*WO2.* Identify methods to maximize the availability of controllers to accommodate surges in traffic. For example, this could be accomplished through alternate schedule designs or strategic utilization of part-time controllers or trainees.

*WO3.* Evaluate how controllers engage with NextGen advancements to identify any unintended interactions with fatigue prior to deployment. For example, require that the development of new tools include fatigue assessments as part of human-in-the-loop testing.

## Controller Staffing Utilization Opportunities (CSUO)

*CSUO1.* Quantify how often scheduled traffic is delayed, leading to increased workload during midnight shifts. Identify and implement methods to support traffic surges during midnight shifts. For example, this could be accomplished by maintaining an option to extend controllers on a swing shift or schedule designs that provide more overlap between shifts.

*CSUO2.* Identify ways that controllers can be re-distributed within a day for a limited number of shifts so that staffing can be adjusted to meet traffic demands. For example, this might involve converting one shift a week to be “on reserve” or scheduling a shift to start within a range of time at the discretion of the manager. It may also be useful to schedule overtime in partial shifts, rather than full shifts to cover episodes of high workload.

*CSUO3.* Refine controller staffing models to better reflect actual work conditions so that they can be used to determine workforce requirements and to guide schedules. Specifically, this should include such factors as actual break durations, appropriate accounting for non-operational duties, adjustments for additional workload factors at a given air traffic facility, etc.

*CSUO4.* Determine how much time controllers dedicate to ancillary assignments. Such information would guide better workforce needs, scheduling decisions, and controller staffing utilization. For example, there may be ways for supervisors to assign such activities during periods of low traffic as opposed to scheduled activities that take controllers off position without regard for traffic activity. Such solutions may enable the recovery of some training time at understaffed facilities.

*CSUO5*. Evaluate and determine if there are effective ways to monitor alertness/fatigue levels when positions are combined and managed by a single controller. For example, this might be done through controller self-assessments, validated fitness-for-duty tests, or through passive monitoring by developing tools or technologies that identify indicators of fatigue from operational data.

*CSUO6.* Specify a minimum duration for recuperative rest breaks for day, evening, and midnight shifts so that controllers can obtain a guaranteed rest duration that also allows time for recovery from the break.

*CSUO7.* Provide explicit FRM education and guidance on how to maximize the benefits of recuperative rest breaks.

*CSUO8.* Recuperative rest breaks may also be beneficial during day or evening shifts. Ensure language and training for recuperative rest breaks is consistent and available across all shift types.

*CSUO9.* Identify approaches to support a guaranteed recuperative rest break for controllers who are working alone. For example, this may include formal procedures to extend a prior shift or advance a later shift, utilize ‘reserve scheduling,’ combine positions across facilities, or temporarily close a sector of airspace to ensure the controller is able to take a recuperative rest break of sufficient duration.

*CSUO10.* Consider clarifying the language that controllers may not sleep while "on position" including appropriate modifications for recuperative rest breaks.

*CSUO11.* Consider allowing controllers to take immediate recuperative rest when they declare themselves fatigued.

*CSUO12.* Consider designating a separate leave category so that fatigue declarations can be tracked more effectively.

*CSUO13.* Review, and where appropriate, reform the process by which controllers declare themselves fatigued so that it minimizes or eliminates potential punitive consequences to the controller.

*CSUO14.* Improve FRM education for controllers specifically related to the use of fatigue reports to enhance the identification of fatigue-related vulnerabilities (e.g., identify facilities where schedule-induced fatigue is elevated, employees with undiagnosed or untreated sleep disorders, etc.).

### Work Environment Opportunities (WEO)

*WEO1.* Identify, test, and deploy a standardized lighting level that allows for optimal alerting, while also assuring lighting is appropriate to meet task needs.

*WEO2.* Enhance the recuperative rest break rooms with consistent amenities between facilities, such as blackout curtains, white noise, and comfortable recliners. Separate recuperative rest areas from other work and active break areas.

*WEO3.* Deploy FRM training material describing best practices for recuperative rest throughout the break rooms so that controllers have easy access to relevant information.

*WEO4.* Identify, test, and deploy enhanced lighting in recreational break rooms to improve controller alertness and performance on the job.

### Operational Requirements Opportunities (ORO)

*ORO1.* Identify and use mechanisms to ensure that known sleep and circadian science as well as FAA/CAMI and other relevant research findings are used to provide input and guide policy, CBA, MOUs, and other scheduling practice efforts. These could include individuals, reports, briefings, etc. that are integrated into working groups or other mechanisms used to address scheduling practices and fatigue management.

*ORO2.* Create, analyze, and use a centralized database of schedules planned and actually worked that includes a national collection of the 313 ATO facilities' schedules and their variations.

*ORO3.* Develop national nominal ATO schedules that reflect the known sleep, circadian, and fatigue science with specific policies, procedures, and guidance for the circumstances and applications to create variations.

*ORO4*. Within an appropriately short timeframe, develop a strategic plan and explicit tactical milestones to determine and deploy a scheduling tool to support facility supervisors' scheduling practices. Incorporate a relevant fatigue risk modeling tool into the scheduling tool or as a component of scheduling procedures. Evaluate the scheduling tool and fatigue risk modeling predictions on a regular basis to ensure optimal effectiveness and value.

*ORO5.* Create and confirm scheduling practices meet operational requirements for safety and efficiency within a structure that provides basic support for sleep and circadian needs while minimizing or mitigating known fatigue risks.

## Employees Needs and Preferences Opportunities (ENPO)

*ENPO1.* Given that most of the data regarding scheduling preferences are about 25 years old, quickly conduct focused surveys to update this information and expand questions to reflect current circumstances and specific schedule features.

*ENPO2.* Ensure that available data (CAMI and others) regarding schedule preferences are included in discussions, deliberations, and decisions regarding potential changes in future scheduling practices. This should include written materials, briefings, and participation in working groups.

## Biological Needs Opportunities (BNO)

*BNO1.* Conduct a thorough examination of the six core scheduling features identified (p.30) using recent and current FAA data to characterize the present state of scheduling practices, including planned vs. actual work schedules.

*BNO2.* Identify and determine specific circumstances around a subset of representative scheduling policy and agreement exceedances then implement mechanisms to monitor and eliminate such exceedances. This effort should be focused on developing and implementing these mechanisms and not involve punitive actions for past circumstances.

*BNO3.* Develop and implement a strategy to eliminate the counterclockwise rotating 2-2-1 schedule and replace it with a schedule design that incorporates sleep and circadian principles.

BNO4. Develop and implement a strategy to update the current prescriptive policies to address identified fatigue factors, especially to avoid known schedule practices that induce fatigue. Specifically, require sufficient time off-duty (e.g., 10-12 hours) before all shifts, whether controllers are performing operational or non-operational tasks. Also, this off-duty time should account for the circadian timing of the shift, where increased off-duty time may be required before midnight shifts.

*BNO5.* Establish a mechanism to track planned vs. actual schedules worked, monitor and address policy and agreement exceedances, and evaluate the effectiveness of scheduling practice changes. Use these mechanisms for regular evaluation of fatigue risks and to implement ongoing enhancements to address sleep, circadian, and fatigue factors in air traffic controller operations.

# Appendix

## Appendix A: Glossary

| | |
|---|---|
| AC | Advisory Circular |
| ARTCC | Air Route Traffic Control Centers |
| ARV | Arrival Runway Verification |
| ATC | Air Traffic Controller |
| ATCS | Air Traffic Control Specialist |
| ATO | Air Traffic Organization |
| ATOMS | Air Traffic Operational Management System |
| ATSAP | Air Traffic Safety Action Program |
| CAMI | Civil Aeromedical Institute |
| CBA | Collective Bargaining Agreement |
| CDO | Cognitive Demands Opportunities |
| CFR | Code of Federal Regulations |
| CPCs | Certified Professional Controllers |
| CPC-Its | Certified Professional Controllers in Training |
| CRWG | Collaborative Resources Workgroup |
| CSUO | Controller Staffing Utilization Opportunities |
| CWP | Controller Workforce Plan |
| FAA | Federal Aviation Administration |
| FARs | Federal Aviation Regulations |
| FRM | Fatigue Risk Management |
| FRMP | Fatigue Risk Management Plan |
| FRMS | Fatigue Risk Management System |
| FRMT | Fatigue Risk Management Team |

| | |
|---|---|
| FSSC | Fatigue Safety Steering Committee |
| FTE | Full-time Equivalent |
| FY | Fiscal Year |
| HO | Health Opportunities |
| IATA | International Air Transport Association |
| ICAO | International Civil Aviation Organization |
| ICSD-3 | *International Classification of Sleep Disorders*, third edition |
| IFALPA | International Federation of Airline Pilots Associations |
| InFO | Information for Operators |
| JO | Job Order |
| MAP | Monitor Alert Parameters |
| MOUs | Memorandum of Understanding |
| NAS | National Airspace System |
| NATCA | National Air Traffic Controllers Association |
| NextGen | Next Generation Air Transportation System |
| NTSB | National Transportation Safety Board |
| OFO | Other Factors Opportunities |
| OPAS | Operational Planning and Scheduling |
| ORO | Operational Requirements Opportunities |
| OSA | Obstructive Sleep Apnea |
| PPR/from | Prescriptive Policies/Regulations and Fatigue Risk Management Opportunities |
| RDO | Regular Days Off |
| SMS | Safety Management System |
| SO | Staffing Opportunities |
| SRT | Safety Review Team |

| | |
|---|---|
| TBFM | Time-Based Flow Management |
| TFDM | Terminal Flight Data Manager |
| TNW | Time Not Worked |
| TRACON | Terminal Radar Approach Controllers |
| TRB | Transportation Research Board |
| UAV | Uncrewed Aerial Vehicle |
| WEO | Work Environment Opportunities |
| WO | Workload Opportunities |

## Appendix B: Acknowledgments

The Scientific Expert Panel would like to acknowledge the valuable cooperation and support received from a variety of stakeholders during this project. The FAA provided subject matter expert liaisons that provided technical and operational expertise, responded to extensive inquiries, and helped the Scientific Expert Panel understand the dynamic complexity of air traffic controller operations. Their expertise and efforts were critical throughout this effort. The Federal Air Surgeon and numerous subject matter experts at the Civil Aerospace Medical Institute (CAMI) provided a variety of resources, briefings, and support for this project. Visits to several facilities gave the Scientific Expert Panel opportunities to directly observe air traffic controller working environments and provided important insights. Thank you to the facility staff and leadership who coordinated these visits.

Senior leadership at the National Air Traffic Controllers Association (NATCA) participated in candid and informative discussions with the Scientific Expert Panel. They provided a critical perspective to the issues that were examined in this report.

The Chairman of the National Transportation Safety Board (NTSB), along with air traffic and fatigue investigators, engaged the Scientific Expert Panel in discussions of relevant past investigations. The Scientific Expert Panel appreciates their thoughtful and distinct perspective.

Former FAA Administrator Michael Huerta provided insights regarding the recent Safety Review Team 2023 Report. Their 2023 Report added unique perspectives to the topics discussed in this report.

The Scientific Expert Panel thanks Dr. Cassie Hilditch at San Jose State University Foundation for her support.

The Panel also acknowledges Jason Sullivan from the Division of Sleep and Circadian Disorders at Brigham and Women's Hospital who provided data analysis in support of the overall project.

Guidehouse provided critical management support throughout this project with specific thanks to Kelsey Glatfelter, Nataliya Sokolowski, and Kathleen Davis, who were invaluable to the project.

## Appendix C: Scientific Expert Panel Membership and Biographies

### *Mark R. Rosekind, Ph.D. (Chair)*

Mark R. Rosekind, Ph.D. was appointed by President Obama, confirmed by the U.S. Senate, and served as the 40th member of the National Transportation Safety Board (NTSB) from 2010 to 2014. Prior to his appointment to the NTSB, Dr. Rosekind founded Alertness Solutions, a scientific consulting firm that specialized in fatigue management, and served as the company's first president and chief scientist. He previously directed the Fatigue Countermeasures Program at the NASA Ames Research Center and was chief of the Aviation Operations Branch in the Flight Management and Human Factors Division. He launched his professional career as the director of the Center for Human Sleep Research at the Stanford University Sleep Disorders and Research Center.

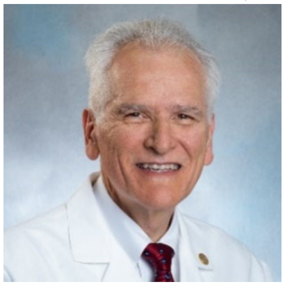
Dr. Rosekind also was appointed by President Obama, confirmed by the U.S. Senate, and served as the 15th Administrator of the National Highway Traffic Safety Administration (NHTSA) from 2014 to 2017. He was the Chief Safety Innovation Officer at Zoox, an Amazon-owned autonomous mobility company, from 2017-2022 and the Distinguished Policy Scholar in the Department of Health Policy and Management at the Johns Hopkins Bloomberg School of Public Health for 2020-2022.

An internationally recognized expert on human fatigue, Dr. Rosekind's work has been widely published, and his awards include the NASA Exceptional Service Medal and six other NASA group/team awards; the Lifetime Achievement Award from the National Sleep Foundation; the Mark O. Hatfield Award for Public Policy from the American Academy of Sleep Medicine; and Fellow of the World Economic Forum in Davos, Switzerland. Dr. Rosekind earned his A.B. with honors from Stanford University, his M.S., M.Phil., and Ph.D. from Yale University, and completed a postdoctoral fellowship at the Brown University Medical School.

### *Erin E. Flynn-Evans, Ph.D., MPH*

Dr. Flynn-Evans is the Director of the Fatigue Countermeasures Laboratory at NASA Ames Research Center. She holds a PhD from the University of Surrey (Guildford, UK) and an MPH from Harvard School of Public Health (Boston, MA). Prior to joining NASA, she was an Instructor in Medicine in the Division of Sleep Medicine at Brigham and Women's Hospital and Harvard Medical School. Dr. Flynn-Evans has extensive research experience examining the short- and long-term effects of sleep loss and circadian misalignment in occupational settings, including among astronauts, airline pilots, physicians, and other shift workers. Her laboratory-based research has focused on examining the effects of light on circadian, neuroendocrine, and neurobehavioral responses in humans and how these outcomes relate to the development of countermeasures for shift work. Her field research has involved integrating these measures of fatigue and associated countermeasures into complex operational settings.

*Charles A. Czeisler, M.D., Ph.D.*



Dr. Charles Czeisler directs the Division of Sleep Medicine at Harvard Medical School, where he is the Frank Baldino, Jr, PhD Professor of Sleep Medicine and Professor of Medicine. He teaches undergraduate courses at Harvard College and is founding Chief of the Division of Sleep and Circadian Disorders and Senior Physician in the Department of Medicine at Brigham and Women's Hospital in Boston, Massachusetts. Dr. Czeisler discovered that retinal light exposure resets the brain's circadian clock in humans, even in some totally blind people, and that light can be used to effectively treat maladaptation to night shift work; discovered that the brain's circadian clock regulates sleep duration and structure; and has applied his research to improve the health and safety of shift work schedules. He characterized fundamental properties of the human circadian pacemaker, including its entrained phase, intrinsic period and resetting capacity; discovered that melatonin can improve misaligned sleep; demonstrated that physicians' extended-duration work shifts adversely affect both patient and physician safety; and designed the clinical trials that led to all three FDA-approved treatments for Circadian Rhythm Sleep-Wake Disorders. Dr. Czeisler directs the largest NIH-supported sleep- and circadian-research training program in the nation, and led NASA's Sleep Team, recording the sleep of astronauts, including Senator John Glenn, during spaceflight and developed sleep-wake schedule guidelines and related countermeasures for use by NASA astronauts and mission control personnel during space exploration; with his colleagues, he received NASA's Innovation Award for designing the solid-state lighting system on the International Space Station to improve the sleep of astronauts. Dr. Czeisler has received the Lifetime Achievement Award from the National Sleep Foundation, the William C. Dement Academic Achievement Award and the Mark O. Hatfield Public Policy Award from the American Academy of Sleep Medicine, the NIOSH Director's Award for Scientific Leadership in Occupational Safety and Health, the Lord Adrian Gold Medal from the Royal Society of Medicine, the Mary A. Carskadon Outstanding Educator Award and the Distinguished Scientist Award from the Sleep Research Society, the Green Cross for Safety Innovation Award from the National Safety Council, the Peter C. Farrell Prize in Sleep Medicine from the Harvard Medical School Division of Sleep Medicine, the Bernese Sleep Award from the University of Bern in Switzerland and the J.E. Wallace Sterling Lifetime Achievement Award in Medicine from the Stanford University School of Medicine. Dr. Czeisler served as President of the Sleep Research Society, Board Chair of the National Sleep Foundation, Chair of the NIH Sleep Disorders Research Advisory Board for the National Center on Sleep Disorders Research of at NHLBI, and faculty for the World Economic Forum (Davos) and Aspen Ideas Festival, and is President-elect of the International Association of Circadian Health Clinics. He is an elected member of the National Academy of Medicine and the International Academy of Astronautics, and was awarded Honorary Fellowships by the Royal College of Physicians (London) and the American Physiological Society.

## Appendix D: Sleep and Circadian Biology

The term "fatigue" can be used to describe many different states. In the context of this report, we define fatigue as the sleepiness or performance impairment that arises from sleep loss, circadian misalignment, or sleep inertia. Individual factors that can affect vulnerability to fatigue are described in Section I(c): Health of this report. The way that these factors influence air traffic controllers depends both on individual-level factors, such as whether a person is vulnerable to the effects of sleep loss or whether a person has a sleep disorder, and work-related factors, such as how schedules are designed and whether countermeasures are available to employees. While the interaction of biological and social factors is complex, many years of research on sleep and circadian rhythms have improved our understanding of how these factors lead to fatigue.

### *Sleep Loss*

Sleep loss manifests in two ways. Acute sleep loss involves staying awake for too many hours in a row, while chronic sleep loss results from not getting enough sleep on a regular basis. Each of these types of sleep loss are common for controllers to experience and are associated with neurobiological changes that contribute to a variety of the symptoms of fatigue.

### *Acute sleep loss due to extended time awake*

The drive for sleep accumulates over time awake and dissipates during sleep. This process is called sleep/wake homeostasis.[1] Neurobiological changes occur over time awake, resulting in the depletion of cognitive resources.[2-8] Alertness and neurocognitive performance steadily decline over time awake,[3, 9, 10-28] such that when a person stays awake for 20-24 hours in a row, their performance is comparable to having a 0.08-0.10% blood alcohol concentration.[29, 30] Such acute sleep loss also impairs judgment,[31-33] cognitive performance,[34-37] memory,[38] reaction time,[1, 21, 39 40] visual-perceptual ability,[1, 41-45] distractibility,[1, 46] and ability to focus attention. Counterintuitively, individuals do not compensate for sleep loss by slowing down, instead, people often increase speed at the expense of accuracy.[41, 47]Acute loss also results in unstable performance, whereby a person may successfully perform tasks for a short duration before losing focus and concentration. This instability is also associated with involuntary transitions to sleep, known as microsleeps,[3, 35, 40] Although air traffic controllers are limited in the number of consecutive hours that they can work, it is possible for them to experience acute sleep loss, particularly during the 2-2-1 schedule.

### *Chronic sleep loss due to insufficient sleep*

Many people do not achieve the recommended 7-8 hours of sleep each night that is required for optimal alertness and performance.[48, 49] Despite this, many people think that they need less than consensus recommendations, but laboratory studies demonstrate that this is not the case for most people. Sleep extension studies, where short sleepers were provided with up to 16 hours time in bed per day reveal that these individuals slept much more and performed much better when given the opportunity[35, 50-53] for more sleep. When people get less sleep than they need, they experience chronic partial sleep loss leading to the accumulation of sleep "debt, which has a negative impact on alertness, performance,[54] and numerous other aspects of cognition, health, and well-being.[33, 35, 46, 55-68] These deficits worsen with each consecutive night of sleep loss.[55, 63, 69-72] Limiting nightly sleep opportunity to four hours for two nights or six hours for seven nights yields performance decrements similar to staying awake for 24 hours.[63, 73] Recovering from chronic partial sleep loss is not straightforward because recovery of different aspects of cognitive function are restored at different rates.[71, 74, 75] Similarly, some components of performance may initially improve after an extended sleep opportunity but rapidly deteriorate over time awake.[76] In many circumstances, it takes more than two nights (i.e., a weekend) to recover from the chronic sleep loss that accumulated throughout the work week.[71, 74, 75] While chronic sleep loss can result in serious impairments, studies demonstrate that individuals are not able to recognize the degree of their impairment. This is particularly important in safety-sensitive occupations such as air traffic control because it means that a chronically sleep-deprived individual may declare themselves to be fit for duty when they are not. Air traffic control schedules can introduce chronic sleep loss, especially during so-called "quick turn" shifts whereby a controller must return to work after only 8-9 hours between shifts.

### *Circadian timing*

The circadian rhythm is an endogenous, self-sustaining internal biological clock that is present in virtually all forms of life. The name circadian is derived from the Latin words circa, "about," and dies, "a day." It is so named because it coordinates many aspects of biological function over 24 hours to align biological function within an individual with the day-night cycle generated by the rotation of the Earth. The circadian pacemaker is a cluster of neurons in the suprachiasmatic nuclei of the hypothalamus in the brain.[15, 16, 22, 77-87]These cells receive direct input from the eyes, which contain specialized photoreceptor cells that detect information about the intensity and wavelength of light.[88] A few of the many functions under circadian control are body temperature, hormone secretion, renal and cardiac function, which all oscillate over 24 hours. [14, 15, 25, 39, 89-102] Importantly, the drive to sleep and wake and many aspects of cognitive function, including alertness and performance are also under circadian control.[15, 16, 91, 99, 103-106] The circadian pacemaker promotes waking during the day and sleep at night. Paradoxically, the strongest drive to be awake occurs in the hours just before one's habitual bedtime,[107] while the drive for sleep is highest during the last part of the night (e.g., ~0300-0600). The timing of this sleep and wake promotion has significant consequences for shift workers, such as air traffic controllers, who must work during the night and who must often shift the timing of their sleep to accommodate work shifts. Specifically, because the strongest drive to be awake immediately precedes one's typical bedtime, it can be very difficult for an individual to fall asleep earlier than usual in order to get enough sleep before an early start work shift. Conversely, during the night, alertness and performance are severely compromised when the circadian rhythm is promoting sleep. This leads to more involuntary transitions to sleep when staying awake during the night, even when one has taken a nap before the night shift. It also results in increased errors,[108] occupational accidents, injuries[109-111] and fatalities,[112, 113] and a greater risk of having a motor vehicle crash during the commute home.

### *Sleep inertia*

The grogginess that individuals feel upon awakening is called sleep inertia.[114, 115] Sleep inertia has a profound effect on alertness and performance and performing tasks immediately upon waking can produce performance impairment worse than that experienced after 24 hours of sleep deprivation.[116] It can take up to two hours for sleep inertia to dissipate,[23, 114, 117, 118] but the worst impairments typically last 20-30 minutes.[119, 120] Sleep inertia can occur upon waking from any sleep episode, but the negative impacts on alertness and performance are worse when one wakes during the maximal circadian drive for sleep,[119] following longer time awake,[121] following longer naps,[122] from slow-wave sleep,[123] and following chronic sleep loss.[114] Sleep inertia is a concern in air traffic control because, like all shift workers, controllers may need to perform shortly after waking from sleep. In particular, taking a nap on a night shift would be accompanied by the greatest burden of sleep inertia. Therefore, it is critical to provide education to controllers on the risks associated with sleep inertia and protected time to allow sleep inertia to dissipate before assigning work tasks.

*Interactions between acute and chronic sleep loss and circadian phase on alertness and performance*

Sleep loss and circadian timing interact in a complex manner that results in significantly worse alertness and performance decrements when combined than any of those factors alone. The way that the circadian rhythm and sleep homeostat interact depends on the time since waking, the time of day that sleep and wake occur, the duration of the prior sleep episode, and sleep history. For example, when a person typically sleeps for 7-8 hours a night, alertness and performance only modestly decline throughout the day. The circadian wake maintenance zone may even lead to improved performance at the end of the day for a rested individual.[124] When an individual wakes earlier or stays up later than normal, performance degrades faster. [28, 72, 90] Similarly, when an individual is awake during the day but is carrying a chronic sleep debt, the decline in alertness and performance is steeper.[56, 72, 125, 126] The greatest performance impairments come when an individual is carrying a burden of sleep loss[56] into the night when the circadian drive to sleep is strongest.[56, 70, 72] This is why the majority of serious fatigue-related incidents, accidents, and motor vehicle crashes occur during the night.[127] Given the nature of 24/7 operations required for most air traffic control facilities, most controllers are likely to experience the combination of these factors throughout a work week. For example, when controllers work day shifts, they will likely commute soon after sleep.[128] This means that they would have minimal time awake while working at a circadian time when waking is being promoted. While controllers working the day shift could experience performance impairment due to chronic sleep loss and early starts, the risk is minimized compared to the midnight shift. During midnight shifts, many controllers may report to work having had little recent sleep, following chronic sleep loss from the prior days of work, and also at an adverse circadian phase. This raises the risk of a controller making a mistake while at work, and elevates the risk of the controller experiencing a drowsy driving crash on the commute home.

*Medication use and medical conditions that impact sleepiness*

There are many medical conditions that are treated with medications that can induce sleepiness. For example, some antidepressants, statins, antihypertensives, hypnotics, antianxiety medications, pain medications, antiepileptic agents, muscle relaxants, and medications to block stomach acid secretion all list sleepiness as a side effect. Similarly, many over-the-counter medications that are used to treat sub-clinical conditions can also induce sleepiness. In particular, antihistamines, which are recommended to treat allergies can cause drowsiness. It is important to consider the impact that these medications might have on a controller's fitness for duty.

While some might view stimulants as a tool to counteract the effects of sleep loss, their effectiveness is dependent on the context of their use. For example, caffeine, the most commonly used stimulant in the world, antagonizes adenosine,[129] which is the neuromodulator that builds up over extended wakefulness,[130] leading to feelings of sleepiness. By blocking the action of adenosine, caffeine can temporarily make one feel more alert and also improve performance, without reducing sleep debt. This means that sleep pressure will continue to accumulate while caffeine is acting, leading to stronger feelings of sleepiness and worse performance as caffeine subsides.[131, 132] In addition, some people begin to rely on caffeine to compensate for chronic sleep deficiency, as evidenced by the counterintuitive finding by the NTSB that caffeine levels were highest among fatal fatigue-related truck crashes.[133], [134] Caffeine also interferes with sleep, leading to further sleep loss. Although it may be helpful for controllers to have access to caffeine to combat unexpected fatigue, it is important to ensure that they are provided with education describing when and how to use caffeine.

Table 2.2 reflects the factors that influence Fatigue and Sleepiness among personnel staffing 24/7 operations.[135]

**Table 2.2. Factors That Influence Fatigue and Sleepiness**

**Circadian rhythmicity (biological time of day)**

A biological clock regulates daily 24-hr rhythms in many aspects of physiology and behavior, including sleepiness and alertness.

All other things being equal, sleepiness and fatigue are greatest in the late-night/early-morning hours.

**Sleep inertia**

When one first awakens, one is typically not at full alertness.

It can take from a few minutes to an hour or more to reach full alertness and cognitive performance levels after awakening.

The reduced alertness and cognitive performance in the time between awakening and reaching full alertness is called "sleep inertia."

The stage of sleep one awakens from, the time of day at which one awakens, how long one has been asleep, and how sleep deficient one is all influence the duration and degree of sleep inertia.

Sleep inertia is most problematic for "on-call" workers who have to perform critical tasks shortly after awakening.

**Time awake**

The longer one is awake, the more sleep pressure one builds up.

In studies in which time awake can be separated from circadian rhythmicity, it is evident that time awake produces a linear increase in sleepiness/fatigue.

During the biological daytime, someone who is well rested will show a fairly stable level of alertness and performance across a ~14- to 16-hr wake episode (after sleep inertia has dissipated). This result is due to an interaction between time awake and circadian rhythmicity.

Some individuals may experience a "postlunch dip," whereby they feel sleepy in the mid-afternoon and then more alert in the early evening.

**Sleep/wake history**

The amount of sleep and wakefulness over the past days (or weeks) influences fatigue/sleepiness.

The quality of recent sleep also contributes to fatigue/sleepiness.

Someone who is sleep deficient (due to poor-quality sleep or short sleep duration) will build up sleepiness much more quickly than someone who is well rested.

The impact of chronic insufficient sleep is often not recognized by the individual experiencing it.

**Time on task**

The duration of performing a task influences fatigue/sleepiness.

Mentally or physically challenging tasks will lead to fatigue/sleepiness more quickly than less demanding tasks.

Breaks can reduce some of the fatigue related to time on task, at least temporarily (but breaks will not change the amount of fatigue/sleepiness related to time awake).

**Medications and medical conditions**

Prescription and over-the-counter medications and medication side effects can influence fatigue and sleepiness directly and indirectly (by disrupting sleep, thereby leading to daytime sleepiness).

Stimulants temporarily reduce sleepiness but may make it difficult to sleep, thereby leading to increased sleepiness the following day.

*(continued)*

**Table 2.2. Factors That Influence Fatigue and Sleepiness (continued)**

| |
|---|
| Alcohol increases sleepiness but interferes with sleep. |
| Pain causes sleep fragmentation and reduces deep sleep, increasing daytime sleepiness and fatigue. |
| Individuals with pulmonary disorders, heartburn, and reflux disorder will have increased symptoms when they lie down, thus disrupting their sleep and increasing daytime sleepiness and fatigue. |
| Restless legs syndrome symptoms increase in the evening and when the individual is at rest, making it difficult to fall asleep. |
| Sleep disorders disrupt sleep, fragmenting it and often also reducing the time spent in certain sleep stages, which leads to daytime sleepiness and fatigue. Many individuals with obstructive sleep apnea have not been diagnosed or do not follow the prescribed treatment. |

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# Appendix E: 2001 CAMI Survey Results


ATCS – TERMINAL AND ENROUTE ISSUE SEPTEMBER 2001

## PURPOSE OF THE STUDY

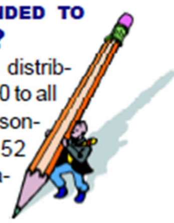
The FAA Air Traffic Control Shiftwork Study was conducted in response to a mandate from Congress to learn more about the shift schedules, sleep patterns, and fatigue of air traffic controllers (ATCS).

*Special thanks go out to all of the individuals who took the time and effort to complete this survey. Your input provided insights about ATC jobs that will be useful in the development of countermeasures for problems associated with working shifts.*

## THIS ISSUE:



## WHO RESPONDED TO THE SURVEY?



The survey was distributed in 1999-2000 to all 23,500 FAA personnel with a 2152 (ATCS) designation.

| | |
|---|---|
| 4,112 | Enroute/Terminal ATCS |
| 1,610 | Mgmt/Staff |
| 900 | AFSS |
| 131 | Option not specified |
| 6,753 | individuals completed the survey |

This pamphlet only addresses the 4,112 enroute and terminal ATCS respondents.

## SHIFT SCHEDULES

The respondents' shift schedules were highly varied across the 3-week period requested in the survey. To assess shift patterns for this pamphlet, comparison schedules for the Enroute/Terminal ATCSs were grouped into 4 categories as shown below with the number of respondents for each category on the right.

| | | |
|---|---|---|
| SS | Straight Shifts (EM, Days, Afternoons) | 44 |
| CR | Counterclockwise, Rapidly Rotating,No mids | 1357 |
| CRM | Counterclockwise, Rapidly Rotating,With mids | 1212 |
| S5R | Straight 5s (Rotate after 5 straight shifts) | 200 |

Note: The remaining 1,299 respondents' shifts did not fit into these 4 categories.

## SHIFTWORK & BIOLOGY

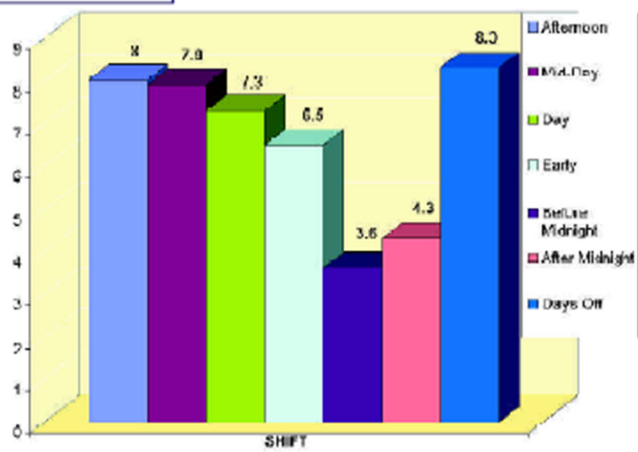
Sometimes shiftwork and our bodies aren't always on the same page. This is because our biological functioning varies over a 24-hour period. These cycles are called circadian rhythms. Many bodily functions have circadian rhythms, such as body temperature, heart rate, sleep and wakefulness, and blood pressure. These activities typically reach a peak level during the day and a low point during the night.

Due to the need to maintain 24-hour coverage in certain facilities, shiftwork is necessary for air traffic control jobs. However, shiftwork can force workers to frequently change their sleep schedule and can throw the body's "clock" out of balance.

92% of the respondents work counterclockwise rotating schedules (e.g., afternoon to days), which goes against our body clock's natural tendencies and can create a "jet lag" feeling.

This pamphlet summarizes the major findings of the shiftwork survey and shows how some of these results relate to your body's circadian rhythms.

Sleep Duration (hours)




**Note: Shift start times were grouped as follows:**

| | | |
|---|---|---|
| Early Morning | Before | 0800 |
| Day | Between | 0800-0959 |
| Mid-day | Between | 1000-1259 |
| Afternoon | Between | 1300-1959 |
| Midnight | Between | 2000-0100 |

## Sleep

The human sleep cycle is divided into several stages.

**Stage I** (10-15 min.) Transitional stage between waking and "light sleeping".

**Stage II** (50% of sleep time) "clinical sleep" when blood pressure drops and heart rate decreases.

**Stages III & IV** "Deep sleep" when the body and mind repair themselves.

**REM Sleep** "Rapid eye movement sleep" usually first occurs 70-90 minutes after the start of sleep. This is when we dream.

This cycle repeats itself several times during sleep.

Shiftworkers must change their sleep patterns with each different shift. When a person significantly changes his/her sleep times, the sleep cycle becomes disrupted.

## Sleep Duration

The chart above shows that ATCSs tend to get the least amount of sleep before and after a midnight shift. Attempting to sleep when the body is programmed to be awake affects the duration and quality of sleep. The sleep before the mid is a good coping strategy even though it is typically several hours shorter than night-time sleep. Other factors that reduce sleep duration include time available between shifts on quick turn-arounds and social/domestic commitments.

## Difficulty Sleeping

ATCS shiftworkers reported more difficulty falling asleep after some shifts than after others. Specifically:

15% - after early shift
11% - after day shift
23% - after mid-day shift
55% - after afternoon shift
62% - before midnight shift
24% - after midnight shift

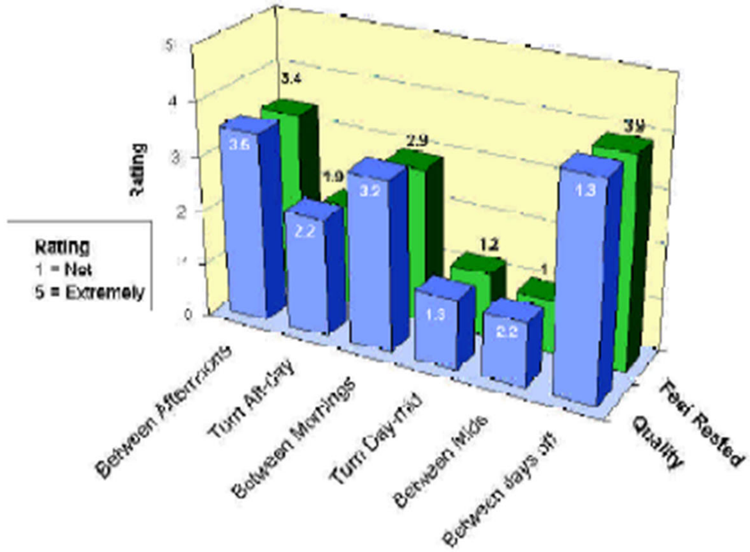
These findings suggest that ATCSs, like other shiftworkers, have more trouble falling asleep during the day (e.g., before midnight) and after the afternoon shift.

Other survey questions found that:

- 67% of ATCS shiftworkers reported having trouble sleeping because of shiftwork.
- 46% of ATCS shiftworkers indicated that they often fall asleep unintentionally.
- 58% of ATCS shiftworkers reported that they nap intentionally.

As a consequence of shiftwork, your body may want to sleep when you shouldn't or don't want to, and at times cannot sleep when you try to.

Ratings of
Sleep Quality and Feeling Rested




### SLEEP QUALITY

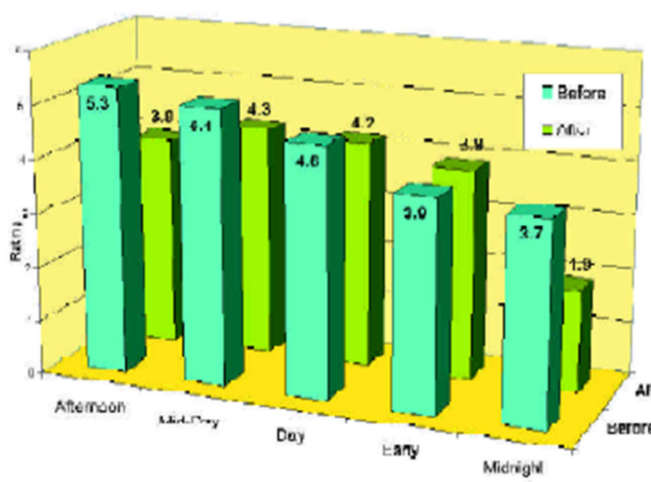
In addition to the amount of sleep and difficulty falling asleep, the quality of sleep and feeling well rested can be affected by working shifts, as shown in the following chart. The chart shows that shiftworking ATCSs experience poorer quality sleep on quick turn arounds and on successive midnight shifts.

## FATIGUE AND RELATED CONSEQUENCES

Reduced sleep, loss of sleep, and disruption of circadian rhythms will result in fatigue. Several trends found in the survey data indicated that alertness and reported tiredness were affected by shiftwork.

### ALERTNESS

The following chart shows that shiftworking ATCSs generally don't feel as mentally sharp after a shift compared with the beginning of the shift.




Mentally Sharp (alertness, memory) Before and After Shifts

- Mental sharpness was lower at the beginning and end of early morning shifts because of a short night sleep and circadian alertness rhythms.
- Mental sharpness was greatest at the beginning of the mid-day and afternoon shifts because your body clock is programmed for daytime rhythms where your temperature is elevated and your mental activity is at its peak.
- Mental sharpness is lowest during the midnight shift because at this time, shiftworkers must deal with the circadian low point for energy and alertness levels, and the effects of poor quality daytime sleep.

### Excessive Tiredness

Daytime alertness is often reduced by excessive sleepiness or tiredness. One survey question directed at sleepiness asked: "In the last year have you caught yourself about to doze off while at work?" The percentage of ATCS shiftworkers responding "Yes" to this question were as follows:

**By Shift:**

- 82% for Early Morning shifts
- 28% for Day shift
- 14% for Mid-day shifts
- 33% for Afternoon shifts
- 62% for Midnight shifts

**By Schedule Type**

- 68% for Straight Shifts
- 65% for Counterclockwise, rapidly rotating, with no midnights
- 77% for Counterclockwise, rapidly rotating, with midnights
- 65% for Straight 5s rotating shifts

Other survey questions showed differences in reporting excessive tiredness across the four shift schedules, as presented in the chart to the left.

### Sleep and Commuting

The difficulties with obtaining enough sleep and good quality sleep are apparent in other areas as well. For example, when factoring in commuting time to and from work, the time available to sleep between shifts is reduced. Quick turn-arounds between shifts (usually, only 8 hours) leave fewer hours available for sleep. Sleeping during the daytime also limits sleep time because your body clock tends to keep you awake.

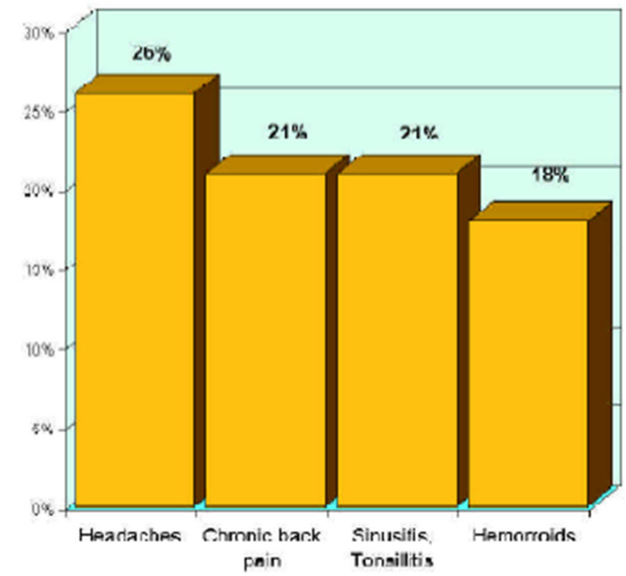
Survey questions about commuting found that a majority of the ATCS shiftworkers reported "sometimes", "frequently", or "always" having a lapse of attention while driving to and from midnight and early morning shifts. Additional questions asked ATCSs whether they had fallen asleep or had an accident while driving home during the last year.

The table below shows a further breakdown of these data.

| SHIFT | Lapses | Fell Asleep | Accident |
|---|---|---|---|
| Early Morning | 66% | 17% | <1% |
| Day | 47% | 8% | <1% |
| Mid-Day | 32% | 5% | <1% |
| Afternoon | 43% | 12% | <1% |
| Midnight | 79% | 36% | 1% |

**More than a third of the controllers reported falling asleep while driving home after a midnight shift.**

The table shows the four most commonly diagnosed illnesses reported by shiftworking ATCSs.




### CHRONIC FATIGUE

Chronic fatigue is a general feeling of tiredness and a lack of energy regardless of whether an individual has not had enough sleep or has been working hard. A person with chronic fatigue feels this way even on rest days and holidays.

Analyses showed that shiftwork contributes to chronic fatigue. More early morning shifts and more rotations were associated with greater levels of chronic fatigue.

### HEALTH

- On average, all ATCSs described their health as "good."
- More than half (52%) of the shiftworking ATCSs exercise on a regular basis.
- On the Digestive Scale, the shift schedules for this pamphlet found that the CRM reported more symptoms than SS and CR; the S5R reported more symptoms than SS.
- On the Cardiovascular Scale, no differences were found for these shift schedules.

The four most frequently reported health complaints were

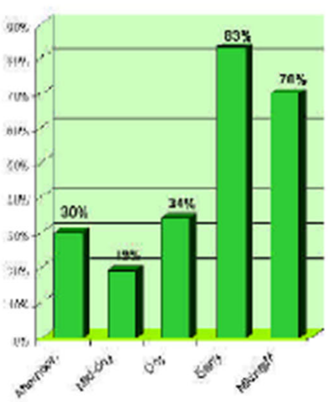
- Bloated stomach, flatulence
- Heartburn, stomachache
- Disturbed appetite
- Must control diet to avoid stomach upset

### SOCIAL/DOMESTIC LIFE

The survey included questions about whether one felt that their shift schedules interfered with leisure or domestic time. The results were as follows:

- On average, ATCSs indicated that their shift schedules at least somewhat interfere with their leisure and domestic time.
- ATCSs working CR, CRM, and S5 schedules reported experiencing more interference than did the SS schedule sample for both leisure and domestic time.

**Shift Percent Indicating Naps Would Be of Most Benefit**



### Coping Strategies

Shiftwork affects people in different ways. Consequently, shiftworkers tend to cope with the effects of shiftwork in different ways and to different degrees.

**Write-in Strategies for Coping with Sleep**

1. Rest or use relaxation techniques (e.g. Yoga, quiet time alone)
2. Take Naps (e.g., after dayshift)
3. Exercise or physical labor (e.g., run, walk)
4. Read
5. Use earplugs or noise blocking devices

The survey respondents were asked to write down the strategies they use to cope with sleep, alertness, and family/domestic life. The most common strategies are reported below:

**Write-in Strategies for Coping with Alertness**

1. Caffeine
2. Exercise
3. Naps

One survey question asked ATCSs, "Do you feel that naps taken on breaks at work would increase your alertness at work?" Of the 80% who responded "yes", they were asked to indicate which applicable shifts would naps be of the most benefit.

**Write-in Strategies for Coping with Family or Domestic Life**

1. Take leave, use credit hours for time off, FFLA
2. Plan time to spend with family (e.g., outings, movies, make quality time)
3. Change work schedule (e.g., adjust work around family time, work part time to avoid certain shifts)

## Survey Write-In Comments

When asked if they had any other comments or observations relating to their sleep and fatigue, the most common response categories were

1. Quick turn-arounds between shifts cause fatigue and/or are dangerous. (164 write-ins)
2. Shiftwork in general causes fatigue, is dangerous, and does not allow a sleep routine. (115 write-ins)
3. Naps should be allowed during breaks. (101 write-ins)
4. Non-work factors (e.g., domestic and social activities) contribute to fatigue. (94 write-ins)
5. Specific shifts are tiring (e.g., midshifts). (88 write-ins)
6. Shiftwork related fatigue causes reduced alertness and loss of focus which causes mistakes or reported/unreported errors. (82 write-ins)

## Conclusions from This Survey and Other Shiftwork Research

1. Shiftwork requires frequent changes in sleep schedules. Such changes disrupt normal sleep patterns and thus reduce the quantity and quality of sleep. Other research has shown that shiftwork leads to sleep loss, fatigue, performance degradation, and increases the likelihood of human error.
2. Some shifts in the survey were found to be disruptive to sleep. The midnight and early morning shifts were identified as the most disruptive.
3. Controllers reported decreases in alertness on midnight and early morning shifts.
4. This study shows that controllers are experiencing lapses of attention and/or falling asleep while driving to or from work. This incident rate is highest after working a midshift, with early morning shifts also being a concern.
5. Current schedules examined in this study showed that some types of schedules were more likely to result in fatigue than others (e.g., schedules with several rotations, particularly those including one or more midnight shifts).
6. The data suggest that controllers are attempting to cope with the demands of shiftwork; however, they are still experiencing fatigue.
7. Other shiftworking populations have reported similar levels of fatigue and health-related effects. This affirms the need to develop additional fatigue countermeasures and educate the workforce on personal coping strategies to mitigate the negative effects of shiftwork.

## ATCS – Terminal and Enroute issue

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# Appendix F: Summary Overview of CAMI Fatigue Work

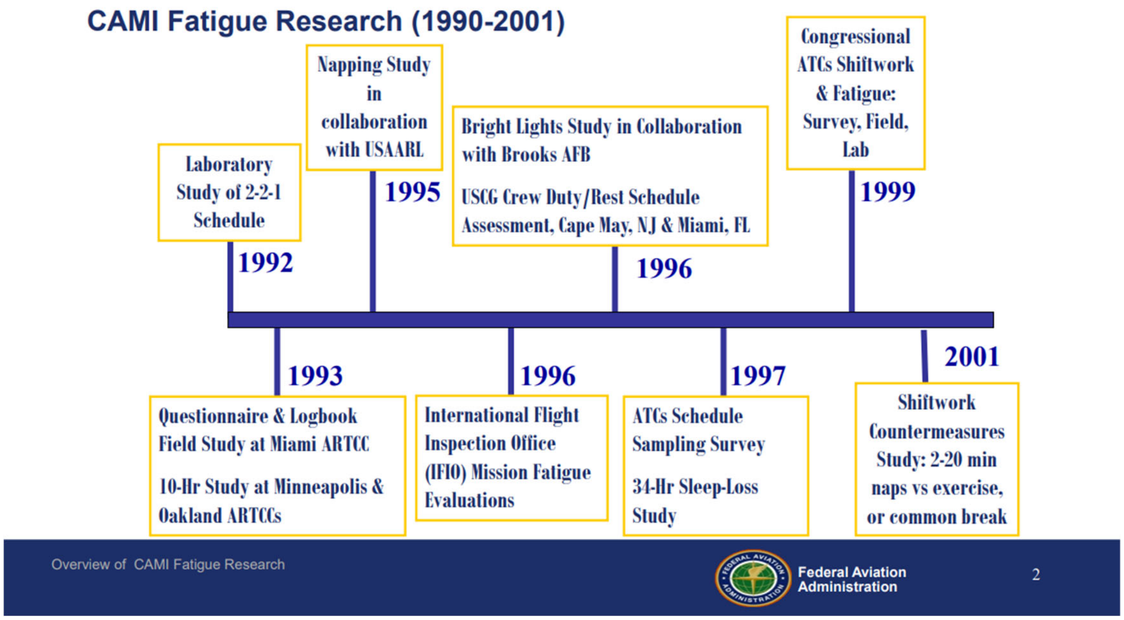


*Figure A- 1*

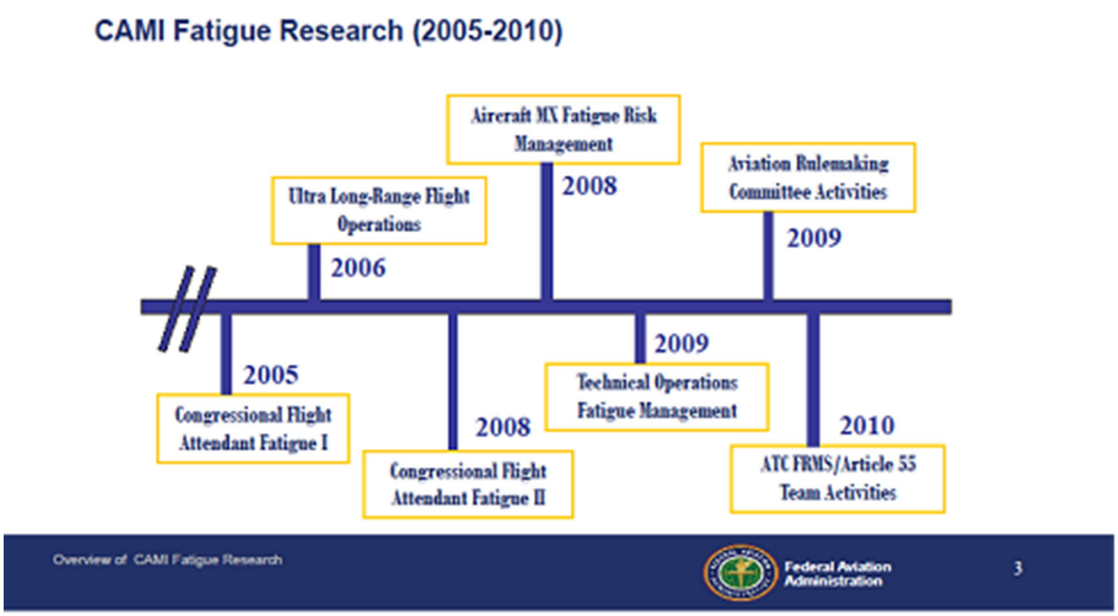


*Figure A- 2*

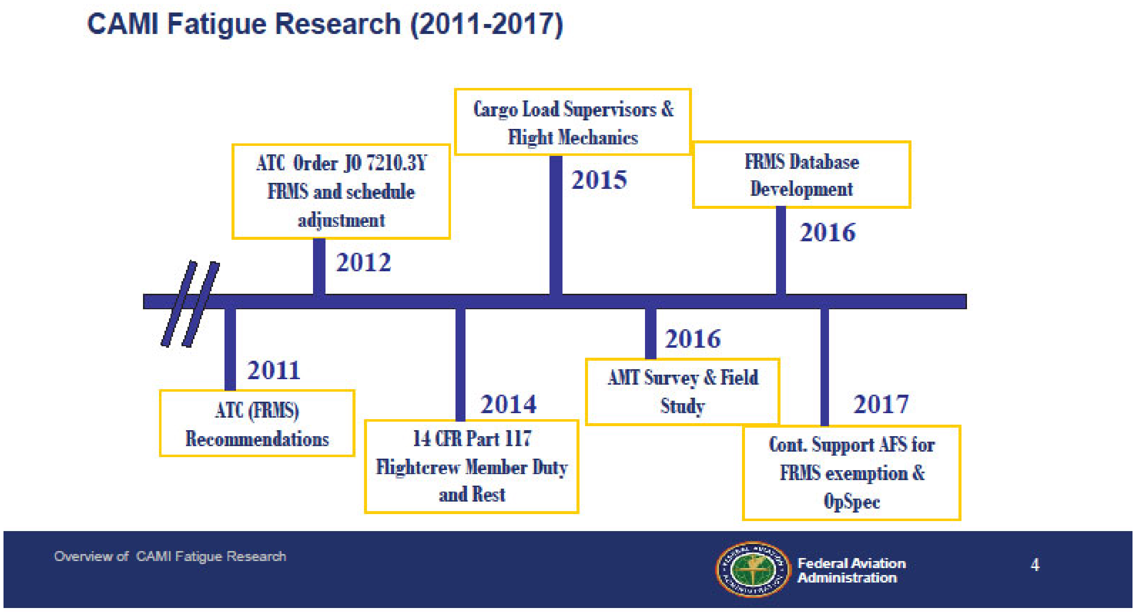


*Figure A- 3*

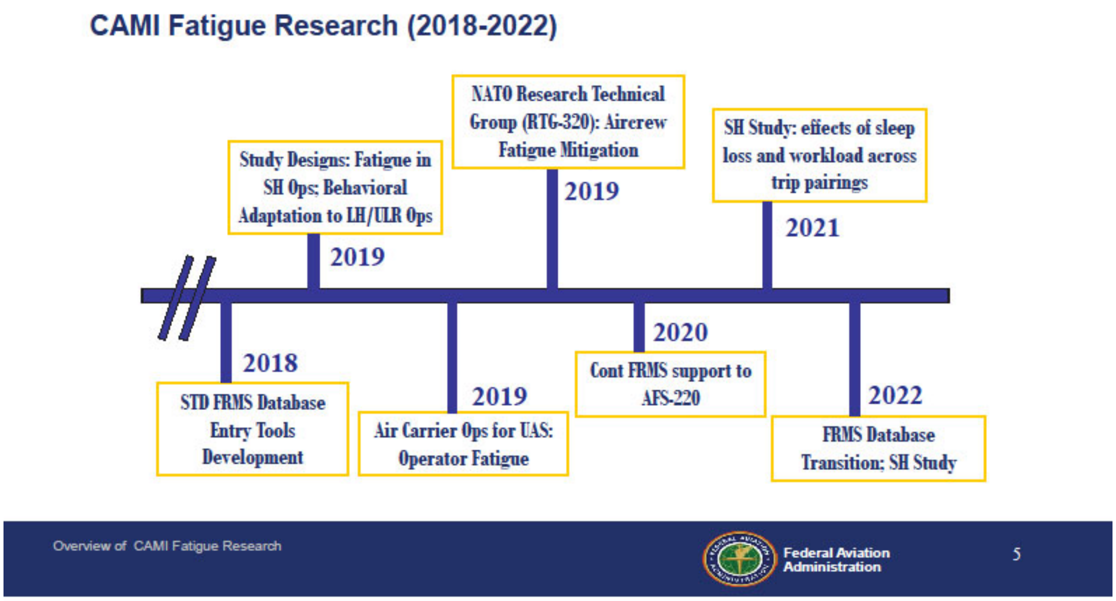


*Figure A- 4*

## Appendix G: CAMI ATC Studies: 1990-2006


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