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THESIS

FATIGUE IN A BRAVERY CULTURE— A COMPARATIVE ANALYSIS

by

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December 2016

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**FATIGUE IN A BRAVERY CULTURE—
A COMPARATIVE ANALYSIS**

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Submitted in partial fulfillment of the
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ABSTRACT

This thesis sought to analyze why the Homeland Security Enterprise (HSE) disregards practices that conform to the scientific understanding of human fatigue and to identify the effective human-error mitigation practices of two other high-consequence fields that may be useful to the HSE. Using the constant comparative method, the command center work environments of the HSE, nuclear power, and air traffic control were analyzed with regard to fatigue-mitigation practices and policies. Despite remarkable similarities in their public safety function and human-technology interface, the resulting grounded theory highlights key differences. In contrast to nuclear power and air traffic control, the HSE has yet to record a serious fatigue incident to serve as a catalyst for change, and unlike those two industries' strong safety cultures, the HSE command centers continue to operate in a deeply rooted bravery culture that prevents the focus on fatigue issues. This thesis brings attention to a clear safety gap and makes practical recommendations that would facilitate the HSE's intentional movement toward a safety culture through the implementation of comprehensive fitness-for-duty programs, multilevel fatigue mitigation training, and the gathering and continual review of human-error data in its command-center work environments.

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TABLE OF CONTENTS

I.	INTRODUCTION.....	1
A.	PROBLEM STATEMENT	1
B.	RESEARCH QUESTION	7
C.	DEFINITION OF KEY TERMS	9
D.	RESEARCH METHOD	12
E.	ORGANIZATION OF THESIS	14
II.	LITERATURE REVIEW	15
A.	HISTORICAL OVERVIEW OF THE STUDY OF FATIGUE	15
B.	HIGH CONSEQUENCE OCCUPATIONS	19
C.	CONCLUSION	31
III.	COMPARISON GROUP ONE—AIR TRAFFIC CONTROL	35
A.	BACKGROUND	35
B.	CATALYST FOR CHANGE IN AVIATION.....	37
C.	AIR TRAFFIC CONTROLLER FATIGUE.....	39
D.	CONCLUSION	46
IV.	COMPARISON GROUP TWO—NUCLEAR POWER PLANT OPERATOR.....	51
A.	BACKGROUND	51
B.	CATALYST FOR CHANGE IN NUCLEAR POWER	52
C.	CONCLUSION	59
V.	HOMELAND SECURITY COMMAND CENTERS.....	63
A.	BACKGROUND	63
B.	INDIANA INTELLIGENCE FUSION CENTER	69
C.	DELAWARE VALLEY INTELLIGENCE CENTER.....	70
D.	CHICAGO CRIME PREVENTION AND INFORMATION CENTER.....	71
E.	CATALYST TO CHANGE—A CASE STUDY OF THE LOS ANGELES POLICE DEPARTMENT.....	71
F.	THE DEVELOPMENT OF REAL-TIME CRIME CENTERS	73
G.	CONCLUSION	75
VI.	DISCUSSION AND ANALYSIS	77
A.	INTRODUCTION.....	77

B.	EVOLUTION OF THE THREE FIELDS' COMMAND CENTERS.....	77
C.	THE ROLE OF THE CULTURE OF BRAVERY	84
D.	COMPARATIVE ANALYSIS OF THE THREE FIELDS' CENTERS.....	88
1.	Fatigue Mitigation Scheduling and Procedures	88
2.	Fatigue Detection and Training	93
3.	Fatigue Mitigation in Law, Regulations, and Labor Contracts.....	94
E.	PUBLIC RECORD OF HUMAN ERROR.....	97
F.	CONCLUSION	99
VII.	CONCLUSION	101
A.	INTRODUCTION.....	101
B.	RECOMMENDATIONS.....	101
1.	Training	102
2.	FFD Programs.....	104
3.	Technology	106
4.	Collection and Use of Human Factor Data.....	107
C.	FUTURE RESEARCH.....	108
D.	CONCLUSION	109
	LIST OF REFERENCES	111
	INITIAL DISTRIBUTION LIST	123

LIST OF FIGURES

Figure 1.	Yerkes and Dodson’s 1908 Study Results.	28
Figure 2.	Example of Counterclockwise Rotating 2-2-1 Schedule.	41
Figure 3.	January 31, 1971, Mission Operations Control Room in the Mission Control Center during the Apollo 14 Manned Moon Mission.	64
Figure 4.	Map of the 78 Fusion Centers.	67
Figure 5.	First Nuclear Reactor and Control Room.	79

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LIST OF TABLES

Table 1. Minimum Day-Off Rules.....56

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LIST OF ACRONYMS AND ABBREVIATIONS

AMRS	Air Mail Radio System
AOR	area of responsibility
ARS	Air Radio System
ATC	air traffic controller
ATO	Air Traffic Organization
ATSAP	Air Traffic Safety Action Program
AWACS	Airborne Warning and Control System
BAC	blood alcohol content
CBA	collective bargaining agreement
CCA	constant comparative analysis
CFR	Code of Federal Regulations
CPC	certified professional controller
CPIC	Chicago Crime Prevention and Information Center
CPO	Chicago Police Officer
DHS	Department of Homeland Security
DOJ	Department of Justice
DVIC	Delaware Valley Intelligence Center
EBR	experimental breeder reactor
ELD	electronic logging device
FAA	Federal Aviation Administration
FCFG	Fusion Center Focus Group
FEAT	Fatigue Education and Awareness Training
FFD	fitness for duty
HHS	Health and Human Services
HPD	Houston Police Department
HRO	High Reliability Organization
HSE	Homeland Security Enterprise
IACP	International Association of Chiefs of Police
IIFC	Indiana Intelligence Fusion Center
IRTPA	Intelligence Reform and Terrorism Prevention Act

LAPD	Los Angeles Police Department
MAW	maximum average work
MOA	memorandum of agreement
MPD	Memphis Police Department
MSLT	multiple sleep latency test
NAS	National Airspace System
NASA	National Aeronauts and Space Administration
NATCA	National Air Traffic Controller Association
NCISP	National Criminal Intelligence Sharing Plan
NENA	National Emergency Number Association
NNFCA	National Fusion Center Assessments
NRC	Nuclear Regulatory Commission
NTSB	National Transportation Safety Board
NYPD	New York City Police Department
PPD	Philadelphia Police Department
RTA	real-time analysis
RTCC	real-time crime center
SLTT	state, local, tribal, territorial
TMI	Three Mile Island
TSA	Transportation Security Administration
USAF	United States Air Force
USPS	United States Postal Service

EXECUTIVE SUMMARY

Human fatigue dominates the literature as an adversary to peak workplace performance; however, not all command centers with public safety missions are equal in their regard for fatigue mitigation. This thesis sought to analyze select command centers of the Homeland Security Enterprise (HSE) and their disregard of practices that conform to the scientific understanding of human fatigue and to identify the effective human error mitigation practices of two other high-consequence fields that may be useful to the HSE. Real-time crime centers of the HSE are relatively new and key to improving public safety, including the detection and prevention of homegrown and lone-wolf terrorism.

This thesis identified two industries (nuclear power generation and air traffic control) with mature command center work environments, and through a constant comparative methodology, a grounded theory to explain the HSE's relatively weaker consideration of practices that conform to the scientific understanding of human fatigue mitigation was developed. Despite remarkable similarities among the three fields of focus in terms of their public safety function and human-technology interface, the resulting grounded theory highlights key differences.

The analysis of aviation and nuclear power command centers revealed that although the regard for fatigue mitigation is not perfect in either field (e.g., some of aviation's flexible scheduling allowances¹), each employs effective fatigue prevention practices and policies that have contributed to making travel and the use of commercial nuclear reactors extremely safe for the public. The two fields continually collect human error data, have clearly defined and monitored policies in place, provide relevant training to key staff, delve into deep investigations of actual or near accidents, and employ well-defined fitness-for-duty assessment procedures. This analysis is largely due to being federally regulated industries, having clear safety cultures, and the concerns relating to past or the perception of potential major catastrophes. It is also related to the aviation and

¹ Federal Aviation Administration, *FAA's Controller Scheduling Practices Can Impact Human Fatigue, Controller Performance, and Agency Costs* (Report Number: AV-2013-120) (Washington, DC: Federal Aviation Administration, 2013), <https://www.oig.dot.gov/sites/default/files/FAA%20Air%20Traffic%20Controller%20Scheduling%20Practices%5E08-27-13.pdf>.

nuclear energy command centers’ evolution into a “safety culture,” which advanced human factor practices following the 1979 Three Mile Island and coined as a term following the 1986 Chernobyl meltdown.² Today, aviation leads in its building of a “safety culture” as perhaps best reflected in the air traffic controllers’ collective bargaining agreement discussion of safety in the context of fatigue mitigation.³

The relatively weak safety culture of the HSE in comparison to aviation and nuclear power in part is due to the fledgling status of HSE command centers, which have yet to experience the severity of serious human error incidents that quickly advanced human factor regulations in the other two fields. Perhaps more significantly, however, the hiring pool for the HSE command centers, which is drawn primarily from line law enforcement personnel, has been mired in a strong “bravery culture” that has carried over to the HSE command centers, preventing it from focusing on fatigue and related human errors. The HSE “bravery culture” appears to be change-resistant in part because, unlike aviation and nuclear science, the HSE is continuously faced with an intelligent adversary. In the present paper’s comparative analysis, achieving mastery or near-mastery over a non-intelligent adversary, as in the science of manned flight or nuclear power, was key to public acceptance. Mastery over an intelligent adversary, the focus of the HSE, is more elusive and not as strongly tied to public acceptance. When failures to master adversaries like terrorists or other types of serious criminals occur, HSE investigations tend to focus primarily on the apprehension of the adversary and not on attributing fault or assessing human performance, such as the accuracy and timeliness of information provided by command center staff.

This thesis proposes key recommendations for the HSE based on best practices of aviation and nuclear power that emerged from the comparative analysis. They can be accomplished largely with existing resources, recognizing that absent a catastrophe, large increases in budgets and regulations are unlikely. The HSE command centers should

² Jan Van Erp, *Safety Culture and the Accident at Three Mile Island* (Argonne, IL: Argonne National Laboratory, 2002), http://www.iaea.org/inis/collection/NCLCollectionStore/_Public/34/007/34007188.pdf.

³ Federal Aviation Administration, *Collective Bargaining Agreement between the National Air Traffic Controllers Association AFL-CIO and the Federal Aviation Administration U.S. Department of Transportation October 2009* (Washington, DC: Federal Aviation Administration, 2009).

develop fitness-for-duty policies and procedures based on those of aviation and nuclear energy that include defining stricter scheduling and return-to-work practices. A comprehensive training program that educates HSE staff on fatigue's complicating factors, identification and assessment of fatigue, and implementation of fatigue counter measures is warranted. In addition, an advanced supervisory training is recommended to qualify supervisors and managers to administer the proposed fitness-for-duty programs. The HSE is also encouraged to create command center procedures for standardized investigations of human-error incidents and near incidents and to adopt advanced technologies designed to identify human fatigue and improve human performance. Implementing this set of recommendations will assist the HSE in a shift from a culture of bravery to one of safety and a clearer path to enhancing public safety consistent with aviation and the nuclear power industries.

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I. INTRODUCTION

A. PROBLEM STATEMENT

This research is focused on the status of fatigue mitigation policies in the high-consequence workplace environments commonly referred to as command centers. Human fatigue and the resulting degradation in human performance is often predictable, and therefore, preventable. In theory, the degree to which fatigue mitigation is of concern to an organization should correspond to the potential for a catastrophic outcome due to human performance error. Organizations often employ command centers to promote efficiency and effectiveness and to guard against key adversaries. However, not all command centers, including those of the Homeland Security Enterprise (HSE), have a similar regard for the one common adversary that they all face, that of human fatigue.

Command centers, as the name suggests, co-locate both personnel and the information or systems needed for taking command action. Air traffic controllers monitor radar enhanced collision avoidance systems and provide directions to pilots on speed, altitude, and course. Nuclear plant operators monitor temperatures, pressures, coolants, and radiation, and make adjustments and sound alarms to prevent or limit radiation exposure. An “all hazard” center may analyze data and other conditions regarding a natural or man-made disaster to advise the public on the proper actions to take.

Sometimes called war rooms or mission control rooms, command centers are intended to provide key personnel with a workspace, equipment, and information designed for situational awareness, operational efficiency, and effectiveness. Command centers exist both in the public and private sectors, and they can be more broadly focused, such as being “all hazard” centers, or being intended for a single purpose, such as those aimed at monitoring for intrusions or fires. Command centers are often the center of attention during or after major incidents, but day-to-day, they help prevent major incidents by making low-level decisions that the general public most often do not notice.¹

¹ Abdul Jaludi, *Command Center Handbook: Proactive IT Monitoring* (North Charleston, SC: Create Space, 2014).

Failures in the command centers of this study have the potential to result in mass human casualties and cause serious damage to the environment or to the nation's economy. While failures come in many types, and may rarely be attributable to a single cause, this study is focused mainly on the cognitive human errors associated with human fatigue. To begin to understand how some command centers evolved to embrace a safety culture around fatigue while others did not, it is worthwhile to begin with the rudiments of a catastrophic incident in the context of key workplace environments.

Air traffic control centers are perhaps the most familiar type of command center. With little fanfare, air traffic controllers working in command centers (e.g., airport towers and regional en route centers), interpret signals and make decisions to maintain safe distances between thousands of aircraft, both airborne and on the ground. The primary adversary and any major incident in air traffic control is therefore any aircraft-involved collision in the air or on the ground. Similarly, in nuclear energy, the main mission is to provide safe and reliable power. The primary adversary to the nuclear energy control room operator is a loss of control over the plant, and ultimately, the unintended release of radiation.

HSE command centers often have far reaching “all hazard” missions that include man-made and natural disasters. However, in terms of preventing major incidents in the HSE command center environments, humans are the most formidable adversaries. The street criminal and the terrorist, unlike aircraft mishaps and radiation leaks, have an intellectual capacity to exploit weaknesses; weaknesses and failures in information sharing were cited as major factors leading to the September 11, 2001 terrorist attacks on the United States. In response, states and localities established what are known today as state and major urban area fusion centers (i.e., a national network of fusion centers).² Fusion centers are multi-agency collaborations numbering 78 in total.³ While some

² Michael McCaul and King Peter, *Majority Staff Report on the National Net-Work of Fusion Centers* (Washington, DC: U.S. House of Representatives, 2013), 1–2, <https://www.archives.gov/isoo/oversight-groups/sltips-pac/staff-report-on-fusion-networks-2013.pdf>.

³ Department of Homeland Security, *2014 National Network of Fusion Centers—Final Report* (Washington, DC: Department of Homeland Security, 2015), 5–9, https://www.dhs.gov/sites/default/files/publications/2014%20National%20Network%20of%20Fusion%20Centers%20Final%20Report_1.pdf.

fusion centers function in high-consequence environments, the vast majority do not. In fact, despite guidelines that recommend that fusion centers operate on a 24-hour-per-day and 7-day-per-week basis, only 22 are in compliance.⁴ In addition to the fact that fusion centers fail to meet the standard of a high consequence workplace environment, they are also unique conglomerations of agencies and policies.

Therefore, the main HSE command center environment for the purpose of this research is the real-time crime center, an emerging type of command center. Most crime centers are largely homogeneous, meaning they tend to be governed and staffed by a single agency. In addition to being ideal for a comparative analysis, the real-time crime center (RTCC) is arguably the most relevant HSE high consequence workplace environment for preventing emerging terrorist threats. Where the fusion center network was designed to prevent the type of communications failures that led to the terrorist attacks of September 11, 2001, it is not designed to handle the emerging terrorist threats by less organized homegrown or lone wolf variety efficiently. In the 2014 *Times* article, “The Rise of the Lone Wolf Terrorist,” Peter Neumann, Director of the International Centre for the Study of Radicalization and Political Violence in London, states that while “lone wolves” may not have an organizational hierarchy (e.g., leadership structure, administration, financing, training, and planning, etc.) as the terrorists who perpetrated the attacks of September 11, 2001, lone wolves “have profound effects in terms of the psychological impact on a society, creating tension, polarization and terror in societies.”⁵ Many criminal organizations, traffickers of narcotics and humans, and terrorists have independent access both to technology and information that facilitates actions without a need for contact, direction, or approval from a larger organizational structure.⁶ Thus, systems created to detect terrorists who are sponsored and assisted by large organizational structures will likely be increasingly less effective against the radicalized street criminal or lone wolf terrorist. Hence, HSE command centers will need to consider

⁴ Department of Homeland Security, *2014 National Network of Fusion Centers—Final Report*, 5–9.

⁵ Naina Bajakal, “The Rise of the Lone Wolf Terrorist,” *Time*, October 23, 2014, <http://time.com/3533581/canada-ottawa-shooting-lone-wolf-terrorism/>.

⁶ Scott Decker and David Pyrooz, “Gangs, Terrorism, and Radicalization,” *Journal of Strategic Security* 4, no. 4 (2011): 151.

ways to update their ability to handle these types of criminals around the clock, an effort that will require closely considering a wider range of adversaries to improve effectiveness, particularly those connected to human errors like fatigue.

Human beings experience performance enhancements and degradations in response to a complex interaction of abilities, limitations, frailties, and other conditions. While individual human differences play a role in performance, no humans are without limits. The broad field of study that seeks to understand these interactions and to develop usable models of human performance is known as *human factors*. Over the past six decades, human factors research has made tremendous gains in this understanding and modeling. The literature is especially strong in the sectors of transportation, energy, medicine, and the human factors related to fatigue.

Aviation and space exploration in the transportation sector emerged especially strong in human factors research. Pioneers in aviation and space exploration were thought of as daredevils and thrill seekers. The nature of aviation from its earliest days until the present has involved failures that can potentially result in the catastrophic losses of passengers, crew, innocent lives on the ground, and costly or limited-quantity equipment.

The energy production sector, especially nuclear energy, also emerged dominant in human factors research. Similar to aviation, the pioneers of nuclear energy faced a formidable but non-intelligent external adversary. Similar to the mysteries of gravity and human flight, nuclear energy pioneers faced radiation, a powerful threat that could not be seen, tasted, or felt until long after the damage was already done. Like pioneers in aviation, pioneers in nuclear energy risked serious injury, illness, and death, which today is a physical risk unique only to workers in a nuclear energy command center. In most other types of command centers, the staff is not at risk for physical injury. For example, air traffic controllers normally do not suffer injury or death in an air catastrophe, and officers working in a HSE command center generally do not face the same physical threats as a field officer or agent.

While no recorded deaths can be attributed to the commercial production of nuclear energy in the United States, the fear of an accidental or intentional release of

radioactive material has resulted in significant regulation in the nuclear energy sector. Fatigue is a primary threat to public safety in the nuclear energy command center environment, which makes this sector an ideal comparison group for the HSE, as is the field of medicine. Medicine, especially emergency medicine, is also well represented in human factors research. Research on human fatigue in the medical field primarily focuses on fatigue associated with the long hours worked by emergency room doctors and nurses. Lengthy work shifts, especially in the early stages of a medical career, are often seen as a rite of passage.⁷ In general, fatigue in the medical field manifests itself as cognitive errors in patient care or in accidents during travel to and from the workplace. In professional medical careers, the decisions can be complex, but in comparison to the decisions made in public safety command centers, even catastrophic outcomes of cognitive errors in the medical profession affect relatively few people on a per incident basis.

The HSE is comprised of all levels of government (i.e., municipal, state, federal, and tribal) and private organizations, employing thousands upon thousands of professionals.⁸ Together, these professionals are responsible for executing five far-reaching Department of Homeland Security (DHS) missions to prevent terrorism, enhance security, manage borders and security, administer and enforce immigration laws, ensure a safe and secure cyberspace, and build a national resilience to disaster.⁹ In comparison to the various aforementioned high-consequence career fields, a potential problem in the HSE begins to emerge concerning the failure to consider the potentially sizeable risks associated with human factor errors. In striking contrast, in the fields of aviation and nuclear safety, as a result of post-incident inquiries and recommendations, the federal government has long established jurisdiction over matters of policy and procedure in these fields. Following aviation and nuclear accidents and near-accidents, the resulting policies and practices have evolved to require comprehensive investigations

⁷ Shao Chuen Tong et al., “Health-Related Quality of Life of Junior Doctors,” *Annals Academy of Medicine—Singapore* 41, no. 10 (2016): 448, <http://www.annals.edu.sg/pdf/41VolNo10Oct2012/V41N10p444.pdf>.

⁸ Department of Homeland Security, *The 2014 Quadrennial Homeland Security Review*, 2nd ed. (Washington, DC: Department of Homeland Security, 2014), <https://www.dhs.gov/sites/default/files/publications/2014-qhsr-final-508.pdf>.

⁹ *Ibid.*, 74–79.

and detailed findings of fault beyond a general attribution of “human error.” As a result, the literature, work rules, and work conditions in the aviation and nuclear career fields are replete with a strong evidence of human factor considerations.

Most HSE public safety missions are remarkably similar to the missions for both the Federal Aviation Administration (FAA) and the Nuclear Regulatory Commission (NRC) in terms of their high consequence for failure. For example, the FAA’s mission is to “provide the safest, most efficient aerospace system in the world,”¹⁰ and the NRC’s mission is to “license and regulate the nation’s civilian use of radioactive materials to protect public health and safety, promote the common defense and security, and to protect the environment.”¹¹ While the HSE mission focuses similarly on public safety, defense, and security, its command center work environments generally have no universal governance, licensing, or credentialing authority. This insufficiency represents an unnecessary, potential threat to the HSE command centers’ ability to carry out the respective agencies’ mission.

In short, a review of the literature and publicly available information revealed no accreditation or other universal fatigue mitigation standards for command center type environments in the homeland security context, representing a serious gap in HSE policy and procedures. Therefore, the current research identifies crucial human factors standards utilized in related fields through a comparative analysis while outlining the evolution of human factor standards that are highly relevant to the mission and work of the HSE. An analysis of the workplace policies of the nuclear plant control room operator and the air traffic controller will be highlighted, as each has a legacy of catastrophes and near catastrophes. The outflow of these actual and near catastrophes has been regulation, comprehensive investigations, and policies to help prevent recurrences, particularly those specific to fatigue and related human errors. In comparing the HSE to these fields, the goal is (1) to identify key human error considerations within the comparison fields, (2) to identify the HSE’s gaps and status in the evolutionary process leading to a safety culture

¹⁰ “Mission,” accessed December 7, 2016, <http://www.faa.gov/about/mission/>.

¹¹ “About NRC,” accessed December 7, 2016, <http://www.nrc.gov/about-nrc.html>.

that incorporates fatigue mitigation in its regulations and policies, and (3) to formulate recommendations that will assist the HSE in accelerating the process.

B. RESEARCH QUESTION

The overarching research question of the current study is how do current practices in command center environments of the HSE conform to the scientific understanding of human fatigue, and how can established practices that mitigate human fatigue and related human factor errors found in other high-consequence fields be useful in improving HSE command center environments. The study will show that HSE command center work environments have a low regard for human factor principles, specifically human fatigue, as compared to other high-consequence and high-reliability organizations. It will also identify best practices aimed at minimizing fatigue and related human factors errors currently implemented in other high-consequence fields that can be useful to HSE centers in their quest to fulfill the mission of protecting the public. Based on the comparative analysis, specific fatigue mitigation recommendations for HSE command centers will be made.

The current study recognizes that given the relatively short period of time that most HSE command centers have been in existence, the HSE command centers selected for comparison likely will lack fatigue mitigation policies and procedures because they have had relatively little time to experience fatigue-related catastrophes, and consequently, to develop related protocols and policies in response to them. As will be argued in the comparative analysis, in general, most high-consequence fields that have integrated comprehensive fatigue considerations have done so in response to catastrophic risks and events over time. Also, it is plausible that the HSE command centers selected for comparison in this study do not face a substantial or actual threat, and therefore, will not likely experience fatigue-related incidents even over long periods of time.

Another consideration is that human errors attributable to the HSE command center may be difficult to document. In other words, a less direct nexus may exist between human error and the actual or near catastrophes common to the comparison command center environments. In practical terms, air traffic control and nuclear energy

control catastrophes have historically been documented as attributable to specific human or mechanical failures or a combination thereof. Human error mishaps in aviation or nuclear energy generally involve specific personnel working in specific command centers. The line between a human error and the resulting adverse outcome has been historically short. In contrast, an act of terrorism or suspected terrorism is a breach of a complex web of overlapping HSE responsibilities. Therefore, following all but the most serious failures and attacks, the HSE may lack the capacity or the political will to attribute any degree of fault to a specific individual or organization.

The current study will limit its focus to high-consequence command centers. Although the medical field has considerable research on and best practice standards in place to mitigate human fatigue and human errors in the workplace, the medical environment generally fails to meet the definition of a command center or high consequence work environment. Hence, the medical field is excluded from a comparative analysis in the present research. Although fusion centers are included, they are not emphasized in the current study. Despite the parallels between HSE fusion centers and other command centers, studies of HSE fusion centers are conspicuously silent on the issues of human fatigue and human error,¹² and as mentioned previously, at present, only 22 of the 78 fusion centers operate around-the-clock in a manner consistent with the characteristics used for comparing command centers.¹³ Further, fusion centers are also multi-agency cooperatives, which were determined to be less than ideal for comparison. Accordingly, the comparative analysis is limited to single-agency high-consequence command centers.

¹² U.S. Department of Justice and U.S. Department of Homeland Security, *Fusion Center Guidelines* (Washington, DC: U.S. Department of Justice and U.S. Department of Homeland Security, 2006), 1–104, http://it.ojp.gov/documents/d/fusion_center_guidelines.pdf.

¹³ Department of Homeland Security, *2014 National Network of Fusion Centers—Final Report*.

C. DEFINITION OF KEY TERMS

The following definitions are key terms used in this study.

Bravery Culture—The term bravery culture is coined in this thesis as a culture wherein the mystique and pride of the collective membership correlates to the actual or perceived dangers. It is a culture in which safety concerns can challenge the value of bravery and courage.

Circadian Rhythms—According to the National Institutes of Health, circadian rhythms are defined as “physical, mental and behavioral changes that follow a roughly 24-hour cycle, responding primarily to light and darkness in an organism’s environment. They are found in most living things, including animals, plants and many tiny microbes. The study of circadian rhythms is called chronobiology.”¹⁴

Command Center—As used in this comparative analysis, a command center workplace is defined as an environment in which humans interface with technology for information management and decision making.¹⁵ Command centers can be operated full-time or activated for the duration of the threat posed by any given incident.

Fusion Centers—According to the DHS, “State and major urban area fusion centers (fusion centers) serve as focal points within the state and local environment for the receipt, analysis, gathering, and sharing of threat-related information between the federal government and state, local, tribal, territorial (SLTT) and private sector partners.”¹⁶

High Consequence Workplace—For the purposes of this comparative analysis, a high consequence workplace is defined as an occupational setting wherein an individual’s precision and accuracy in cognitive functions and human error, (i.e., acts or omissions) in decision making and data interpretation could reasonably be correlated to the widespread

¹⁴ “Overview of Circadian Rhythms,” accessed December 7, 2016, <http://pubs.niaaa.nih.gov/publications/arh25-2/85-93.htm>.

¹⁵ Steven Davis, *Making Your Command Center a Success* (Columbia, MD: DavisLogic, Inc., 1999), 1–4, <http://www.davislogic.com/Command%20Center%20Article.doc>.

¹⁶ “About Fusion Centers,” accessed December 7, 2016, <https://www.dhs.gov/state-and-major-urban-area-fusion-centers>.

loss of life or severe damage to the environment or economy. This term is related to the term high reliability organization (HRO).

High Reliability Organization—In Gregory Bigley and Karlene Roberts’ 2001 research, HROs are defined as “systems that exhibit continuous, nearly error-free operation, even in multifaceted, turbulent, and dangerous task environments.”¹⁷ In that same work, Bigley and Roberts provide examples of HROs, including, “nuclear power generation plants, air traffic control, and space launch vehicles.”¹⁸

Homegrown Terrorist(s)—A homegrown terrorist can be an individual (also see: lone wolf) or groups of individuals with little or no direct association with an international group.¹⁹ For the purposes of this research, a homegrown terrorist also commits acts in the furtherance of ideological, political, or religious change against the interests of the country in which they reside or hold citizenship.²⁰

Human Error—According to Duke University definitions, and based on work by Professor of Psychology, Dr. James Reason, “an error is a circumstance in which planned actions fail to achieve the desired outcome.”²¹ Dr. Reason completes the definition by adding that “human error” means that the undesirable outcome could have been mitigated or avoided if the individual had acted differently.²²

Human Fatigue—Human fatigue is commonly defined as objective symptoms of a person, described as feeling tired, weary, or having low energy. Fatigue is a normal response to physical exertion, emotional stress, mundane activity or a lack of activity

¹⁷ Gregory A. Bigley and Karlene H. Roberts, “The Incident Command System: High-Reliability Organizing for Complex and Volatile Task Environments,” *Academy of Management Journal* 44, no. 6 (2001): 1281–1299, doi: 10.2307/3069401.

¹⁸ Ibid.

¹⁹ Courtney Richardson, Marion E. Bowman, and Kimberley L. Thachuk, *Homegrown Terrorism: The Threat Within* (Washington, DC: National Defense University, 2008), 2, <http://www.dtic.mil/cgi-bin/GetTRDoc?AD=ada482139>.

²⁰ Abu Khawla, “Understanding Homegrown Terrorism,” *American Thinker*, December 12, 2010, http://www.americanthinker.com/articles/2010/12/understanding_homegrown_terror.html.

²¹ “Anatomy of an Error, Definitions of Error,” accessed December 7, 2016, http://patientsafetyed.duhs.duke.edu/module_e/definitions.html.

²² Ibid.

(e.g., boredom) or a lack of adequate sleep. While not a serious condition, fatigue by itself can be an indicator of a more serious medical condition.²³

Lone Wolf Terrorism—In their recent work, *Report: Lone Wolf Terrorism*, Lydia Alfaro-Gonzalez et al., determined that no universally accepted definition was available for the term “lone wolf terrorism.”²⁴ In agreement with that assessment, the present author has selected the following working definition from Peter J. Phillips’ 2011 work, *Lone Wolf Terrorism*, “lone wolf terrorists are individuals who operate alone, without accomplices and outside of a formal terrorist organization or command structure.”²⁵

Real-Time Crime Center A RTCC is a facility at which state of the art technology is co-located with investigators and analysts to acquire and develop information to prevent crime and identify offenders. It is widely accepted that the first RTCC was deployed by the New York City Police Department (NYPD), followed shortly thereafter by the Los Angeles Police Department (LAPD), and the Houston Police Department (HPD).²⁶ While definitions for RTCCs vary from city to city, they represent a solution for organizations dealing with otherwise unmanageable volumes of data (e.g., video inputs, incident and criminal complaints, arrest records, photos, national crime databases, and 9-1-1 call records) that when effectively analyzed, can lead to the prevention of serious crimes up to and including terrorism.²⁷

Safety Culture—According to the Nuclear Regulatory Commission, and consistent with many other definitions, “a safety culture is a culture in which the core values and behaviors resulting from a collective commitment by leaders and individuals

²³ “Fatigue,” last updated November 1, 2016, <https://medlineplus.gov/ency/article/003088.htm>.

²⁴ Lydia Alfaro-Gonzalez et al., *Report: Lone Wolf Terrorism* (Washington, DC: Georgetown University, 2015), 9, <http://georgetownsecuritystudiesreview.org/wp-content/uploads/2015/08/NCITF-Final-Paper.pdf>.

²⁵ Peter J. Phillips, “Lone Wolf Terrorism,” *Peace Economics, Peace Science and Public Policy* 17, no. 1 (2011): 1, https://eprints.usq.edu.au/18630/2/Phillips_PEPSPP_v17n1_PV.pdf.

²⁶ *Wikipedia*, s.v. “Real Time Crime Center,” last modified May 25, 2016, https://en.wikipedia.org/wiki/Real_Time_Crime_Center.

²⁷ Michael Fox, “How Real-Time Crime Center Technologies Are Force Multipliers,” *PoliceOne*, April 14, 2014, <https://www.policeone.com/police-products/police-technology/articles/7083433-How-real-time-crime-center-technologies-are-force-multipliers/>.

emphasize safety over competing goals to ensure protection of people and the environment.”²⁸ A safety culture is most often found in organizations responsible for managing hazardous activities, maintaining public confidence, and achieving the lowest possible risk to people and the environment.²⁹

Shift Work—This type of work is most common in hospitals, companies, factories (e.g., automobile, petrochemical and textile factories), or other businesses open and operating 24/7 or hours outside of the usual “9 to 5” business hours.³⁰ Command center workers are necessarily subject to shift work and the rotation of shifts, which can contradict peak human performance.

D. RESEARCH METHOD

This research is based on the constant comparative method, the outflow of which is intended to produce a grounded theory related to an apparent disparate regard for the effects of human fatigue in the HSE when compared to other high consequence occupations. Constant comparative analysis (CCA) was developed in 1967 by Barney Glaser and Anselm Strauss to facilitate a deep, qualitative exploration of patterns and relationships among concepts or information. The method is especially useful when gathering accurate data is difficult because of real or perceived barriers to access, such as when the information is classified, confidential or sensitive, when the information can be taboo, or when the release of the information can be stigmatizing.³¹ The constant comparative method presumes that entities like those contained in the HSE, aviation, and nuclear power fields, the fields of focus in this thesis, would be against full disclosure, which the author experienced. Ultimately, adequate data was obtained that allowed for a comparative analysis of these fields, which emphasized the historical development of command center environments and their evolving fatigue mitigation policies. The

²⁸ “Safety Culture,” last reviewed/updated March 3, 2016, <http://www.nrc.gov/about-nrc/safety-culture.html>.

²⁹ “Safety Culture.”

³⁰ *TheFreeDictionary*, s.v. “Shift Work,” accessed December 7, 2016, <http://medical-dictionary.thefreedictionary.com/Third+shift>.

³¹ Barney G. Glaser and Anselm L. Strauss, *The Discovery of Grounded Theory* (Chicago: Aldine Pub. Co., 1967).

variables included in the analysis were a range of safety workplace policies and practices, both general and those expressly intended for fatigue mitigation.

In light of the anticipated hesitancy of agencies at the heart of this CCA, four sources and modes of data collection were employed. First, a library database search was conducted to identify scholarly research articles and reports on command center policies and fatigue mitigation practices and the impacts on a range of relevant fields, but was later narrowed down to three: homeland security, nuclear industry, and aviation. Initially, this paper intended to include a wider array of career fields in which fatigue can play a serious role to safety, such as emergency medicine, but they were eliminated from study because their fatigue related errors were typically not associated with a command center operation, technology, or mass casualties.

Second, a search for reports available on relevant agency websites was conducted, which were largely declassified audits and other publicly available assessments. Third, formal public information requests were served to the Nuclear Regulatory Commission, the Federal Aviation Administration, and select HSE command centers (primarily real-time crime centers) for documents and reports relevant to the mitigation of human fatigue and the prevention of human error. In regards to obtaining data specific to fatigue-related employee scheduling practices, formal information requests were made to regulatory agencies and collective bargaining organizations that contribute to scheduling policies governance documents (e.g., codes, ordinances, case law, statutes) in the three fields of focus in this study.

The fourth method of data collection was through participant observation. The current author is a career peace officer, having been employed in the Air National Guard, university, and major city police agencies for over three decades. The current author has served for over 28 years as a sworn member of the Los Angeles Police Department, and over the five most recent years leading up to the writing of this thesis, he served as a member of the command staff team. He had ready access to the LAPD's real-time crime center, at which he served as the commanding officer for two years. As a participant observer, the present author was able to observe command center behaviors and patterns

not readily available to individuals external to the LAPD and had streamlined access to documents related to fatigue mitigation within his large public safety agency.

The information gathered from the Nuclear Regulatory Commission, the Federal Aviation Administration, select HSE command centers, relevant government oversight and bargaining organizations, scholarly articles, and the author's notes as a participant observer were analyzed and compared along several dimensions: a historical review of each field's command centers in regards to catastrophes and catalysts for shifts in the focus on human error, the numbers and types of human errors and their resulting impacts, if any, staff scheduling patterns and trainings, fitness-for-duty practices, and specific protocols and other policies in place related to mitigating fatigue and related human error, such as drug testing, the use of technology, moonlighting, and overtime restrictions. The CCA included a consideration of factors that may have contributed to the HSE's disregard for human factors errors, as well as recommendations for the agency to consider in looking ahead.

E. ORGANIZATION OF THESIS

This thesis is divided into seven chapters. Following this introductory chapter, Chapter II consists of a review and synthesis of the recent and relevant scholarly work on human fatigue and related human errors in high consequence environments. Chapter III is a brief overview of the history, evolution, and current state of affairs significant to human and related errors in air traffic control, followed by Chapter IV, which provides a similar discussion of the history, evolution, and current state of affairs in nuclear energy. Chapter V provides a detailed analysis of the history and culture of the HSE and its RTCC, with a brief review of its fusion centers and an analysis of its data and considerations of human error. Chapter VI focuses on a comprehensive, yet detailed comparison of the three agencies, highlighting similarities and differences in how the agencies function, including types of catastrophes and resulting best practices in the nuclear power and air traffic fields. The conclusion in Chapter VII summarizes the comparisons and gaps in HSE's policies and protocols regarding fatigue and related human errors, and provides several recommendations for mitigating these types of errors in the future.

II. LITERATURE REVIEW

A. HISTORICAL OVERVIEW OF THE STUDY OF FATIGUE

The early works on fatigue examined performance degradations related to crop yields, which indicated that even soil needed restorative rest.³² Volumes have been written on the issue of metal fatigue dating back to the mid-1800s and the studies of William John Macquorn Rankine.³³ In the well over 100 year-old work by Rankine, catastrophic failures in metal axles resulted in the use of the word “fatigue” in the manner used throughout the literature.³⁴ In his 19th century work, Rankine noted failures in metal parts that had performed satisfactorily for a period of time and concluded that “the continual re-application of the load had in some way exhausted the ability of the material.”³⁵ It was the belief in Rankine’s day that the material had “tired of carrying the load.”³⁶ In short, both soil and metal fall victim to exhaustion and need rest for optimal performance. Metal, in particular, can weaken, yet its appearance is often not a useful or reliable indicator of imminent failure; a situation known through considerable research to apply to humans as well.

Humans and other living things (e.g., bacteria, fungi, plants, fish, and mice) are known to have predictable performance rhythms. The term “circadian” is a derivation of “circa diem,” which is a Latin phrase meaning “about the day,” and is found throughout the literature on the performance and behavior of living things.³⁷ The earliest known work on circadian rhythms belongs to French scientist de Mairan, who wrote in the 1700s

³² Hugh H. Bennett, *Soil Conservation* (New York: McGraw-Hill Book Co., 1939).

³³ “William John Macquorn Rankine (1820–1872), Engineer, Polymath, Educator and Researcher. Pioneer of Thermodynamics,” accessed December 7, 2016, <http://www.engineeringhalloffame.org/profile-rankine.html>.

³⁴ Von N. E. Frost, K. J. Marsh, and L. P. Pook, *Metal Fatigue* (Oxford [England]: Clarendon Press, 1974).

³⁵ *Ibid.*

³⁶ *Ibid.*

³⁷ Fred W. Turek, Joseph S. Takahashi, and Martha Hotz Vitaterna, “Overview of Circadian Rhythms,” *Alcohol Research and Health* 25, no. 2 (2001): 85–93, https://www.researchgate.net/profile/Joseph_Takahashi/publication/11764172_Overview_of_circadian_rhythms/links/0c960525dc638d9dfe000000.pdf.

about the predictability of leaf movements of a plant throughout the day. In de Mairan's experiment, plants removed from sunlight continued to raise and lower their leaves, strongly suggesting the existence of an internal clock and not a mere reaction to sunlight.³⁸

While most living things tend to obey their circadian rhythms, humans, especially those engaged in shift work, can decide to disrupt their individual circadian rhythms at the expense of wellness and performance.³⁹ The early work on circadian rhythms suggested one general pattern or one optimal time of day exists for peak human performance. In Groeger's more recent work on youthful drivers, individual attributes, such as age, social status, and technical experience, contributed to reduced opportunities for sleep and contradicted the belief of a universal peak performance clock for humans.⁴⁰ Although it may be helpful to leaders in high-consequence fields to understand the potential risks associated with individual differences and especially those correlated with reduced opportunities for sleep, indisputably, human limits to peak and even adequate performance do exist. Just as with metal and soil, human fatigue is eventually inevitable, and in fact, agreement is widespread on the adverse effects of sleep deprivation on human performance.⁴¹ The manifestations of the degradations include a lack of accuracy, faulty decision making, a lack of physical coordination, and irritability.

In an earlier study by Ardith Zwyghuizen-Doorenbos et al., the nighttime sleep patterns and daytime performance and personalities of healthy asymptomatic young men were compared using the multiple sleep latency test (MSLT), a scientifically validated test that measures the time taken to fall asleep at specific intervals in a quiet daytime

³⁸ Turek, Takahashi, and Hotz Vitaterna, "Overview of Circadian Rhythms," 86.

³⁹ Ibid.

⁴⁰ John A. Groeger, *Youthfulness, Inexperience, and Sleep Loss: The Problems Young Drivers Face and Those They Pose for Us* (Guildford, UK: Injury Prevention, 2006), <http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.551.6334&rep=rep1&type=pdf>.

⁴¹ Donna L. Arand and Michael H. Bonnet, *We Are Chronically Sleep Deprived* (Dayton OH: American Sleep Disorders Association and Sleep Research Society, 1995), https://www.researchgate.net/profile/Michael_Bonnet/publication/14456961_We_are_chronically_sleep_deprived._Sleep_18_908-911/links/09e41508ecb8bb8040000000.pdf.

environment.⁴² Eighteen of the study's participants were dubbed the "sleepy" group because they scored an average of less than six minutes to fall asleep based on the MSLT. Twenty of the young men fell into the "alert" group because they scored an average of greater than 16 minutes on the MSLT. Further, the sleepy subjects performed more poorly than their alert counterparts on both divided attention and vigilance performance tasks. The sleepy subjects' reduced performance was especially notable considering they were better at falling and staying asleep (i.e., got more sleep and likely slept more soundly) than the alert subjects.

Perhaps the most unique of all human fatigue studies ventured into the science of emotional intelligence conducted by William D. S. Killgore et al.⁴³ In their study, 26 healthy individuals completed two testing instruments (Bar-On Emotional Quotient Inventory and the Constructive Thinking Inventory) to test the impact of sleep deprivation on emotional and cognitive intelligence at three time intervals: rested, 55.5 hours of continuous wakefulness, and 58 hours of continual wakefulness. In comparing subject performance in both simple and complex tasks during a baseline period of adequate rest to their performance in the same tasking following two extended periods of wakefulness, Killgore et al. found both physical and mental performance degradations to be linked to the subjects objectively in need of rest. Killgore et al. found that sleep deprivation was associated with a variety of outcomes objectively detrimental to optimal human decision making, such as significant reductions in assertiveness, a sense of independence, impulse control, and positive thinking, as well as a "greater reliance on formal superstitions and magical thinking processes."⁴⁴ The study's value lies not only with its scientific documentation of the impact of fatigue on higher level thinking about and responding to emotional information, but with fatigue's ability to generate irrational thought processes, such as magical thinking, which is critically important to consider for high consequence work environments.

⁴² Ardith Zwyghuizen-Doorenbos et al., "Effects of Caffeine on Alertness," *Psychopharmacology* 100, no. 1 (1990): 36–39, doi: 10.1007/bf02245786.

⁴³ William D. S. Killgore et al., "Sleep Deprivation Reduces Perceived Emotional Intelligence and Constructive Thinking Skills," *Sleep Medicine* 9, no. 5 (2008): 517–526, doi: 10.1016/j.sleep.2007.07.003.

⁴⁴ *Ibid.*, 517.

With respect to the role of fatigue in the workplace, a key study conducted in Sweden revealed a link between occupational (not necessarily police or HSE specific) accidents to fatigue.⁴⁵ The large-scale Torbjorn Åkerstedt et al. study tracked over 47,000 working individuals (both males and females) over two decades, analyzing self-reported accident rates, sleep patterns, and health symptoms. At the conclusion of the study, 166 fatal occupational accidents and a range of fatigue-related symptoms had occurred, including self-reported sleep problems. Most importantly, those who had non-day work shifts had a significantly higher rate of accidental death at work. During the 20-year period, 124 males and 42 females experienced fatal accidents (suicides and poisonings excluded), with males over twice as likely as females to experience them. Participants who reported difficulty in sleeping in the previous two weeks had a relative risk of 1.89 compared to individuals with no sleep difficulties. Further, overall, non-day workers had a relative risk score close to that of those who reported sleep difficulties, suggesting that a lack of sleep was related to an increased risk for accidents among those working evening and night shifts. The study is of particular importance because it utilizes an unusually large sample population and a longitudinal design spanning over two decades. Nonetheless, weaknesses resulted in that information was gathered by telephonic interviews and the data relied on self-reporting, which tends to be subjective. However, given the large sample size, the study provides some insight into the contribution of long work hours and non-day shift work on performance.

The Åkerstedt et al. study suggests that a correlation exists between working during the hours most humans would ideally be sleeping and the risk of accidents and potential catastrophes, likely due to the role of fatigue. The early literature on the causes of major catastrophes often attributed a primary cause and secondary, or lesser, contributing factors to major catastrophes that include human error.⁴⁶ Despite older studies and more updated ones, such as that of Åkerstedt et al., that suggest humans are

⁴⁵ Torbjorn Åkerstedt et al., “A Prospective Study of Fatal Occupational Accidents—Relationship to Sleeping Difficulties and Occupational Factors,” *Journal of Sleep Research* 11, no. 1 (2002): 69–71, doi: 10.1046/j.1365-2869.2002.00287.x.

⁴⁶ “1986 Report of the Presidential Commission on the Space Shuttle Challenger Accident,” accessed December 7, 2016, <http://history.nasa.gov/rogersrep/genindex.htm>.

not well designed for 24/7 operations, shift work is often a requirement in high consequence work environments, such as the command centers of the HSE. The remainder of this literature review discusses the specific workplace factors that contribute to fatigue in high-consequence fields and how they impact the ability to meet public safety goals.

B. HIGH CONSEQUENCE OCCUPATIONS

The vast majority of scholarly work on human fatigue is concentrated in three primary disciplines considered high consequence occupational fields: emergency medicine (primarily emergency room doctors, nurses, and technicians), transportation (to include commercial pilots, air traffic controllers, maritime pilots, long-haul truckers, and space exploration), industrial technology (mostly high consequence occupations, such as nuclear power plant engineers and petroleum plant operators). The focus on these occupations has been of considerable scholarly interest because fatigue and related human errors can result in cascading effects of monumental proportions on either individuals or entire communities. The literature in these areas is heavily weighted toward studies of sleep deprivation, the length of work shifts, and rest time before returning to work.

Two studies of particular interest involved vastly different high consequence occupations (new doctors and truck drivers). In the United States and other countries, truck drivers and doctors have traditionally worked very long shifts, yet for years, gaps remained in the understanding of the effects of long shifts on health and safety.⁴⁷ However, a few more recent studies have begun to shed light on the issue.

In a 2005 study by Laura K. Barger et al., 2,737 medical doctors doing their first year residency collectively completed over 17,000 monthly web-based reports that provided detailed information about work hours, extended work shifts, traffic collisions, actual and near-miss accidents, and incidents of unintended sleep.⁴⁸ The researchers

⁴⁷ Laura K. Barger et al., “Extended Work Shifts and the Risk of Motor Vehicle Crashes among Interns,” *New England Journal of Medicine* 352, no. 2 (2005): 125, doi: 10.1056/nejmoa041401.

⁴⁸ Ibid.

found that when comparing a standard shift with a shift of an extended duration (i.e., > 24 hours), the odds ratio for a motor vehicle crash and near motor vehicle crash were 2.30 and 5.9, respectively. In cases in which the new doctors worked five or more extended shifts, they were at significantly increased risk of falling asleep while actively driving a motor vehicle and while stopped in traffic (odds ratios were, 2.39 and 3.69, respectively).

Similar results were found in a slightly older study focusing on long-haul truck drivers that sought to understand and mitigate the risks in this high consequence occupation. In 1997, Merrill M. Mitler et al. noted that “annually over 110,000 people are injured and more than 5000 killed in the United States in motor vehicle accidents involving commercial trucks.”⁴⁹ Their study consisted of full-time (24-hours per day) electronic monitoring of 80 commercial truck drivers who worked day, night, or irregular shifts in the United States and Canada. While no crashes occurred during the timeframe studied, the authors cited studies and governmental sources that indicated that up to 56 percent of commercial truck crashes were either completely or partially attributable to fatigue.⁵⁰ Although its sample size was small, the investigation was influential because it utilized electronic devices to measure scientifically verifiable stages of sleep and levels of awareness. Most past studies, including those specific to law enforcement, used self-report survey instruments, which provide more subjective data. Interestingly, Mitler et al. found that the complexity of the task to be performed was not a primary causal factor, with the exception that fatigue was more problematic during the monotony of the long-haul truck-driving task.⁵¹

⁴⁹ Merrill M. Mitler et al., “The Sleep of Long-Haul Truck Drivers,” *New England Journal of Medicine* 337, no. 11 (1997): 755–762, doi: 10.1056/nejm199709113371106.

⁵⁰ Mitler et al. cited three sources in support of the assertion that 1% to 56% of commercial truck accidents were related to fatigue: Center for National Truck Statistics, *Truck and Bus Accident Factbook 1994* (Report no. UMTRI-96-40) (Washington, DC: Federal Highway Administration Office of Motor Carriers, 1996); R. R. Knipling and J. S. Wang, *Crashes and Fatalities Related to Driver Drowsiness/Fatigue: Research Note* (Washington, DC: National Highway Traffic Safety Administration, 1994); J. R. Treat et al., *Tri-level Study of the Causes of Traffic Accidents* (Publication no. DOT-HS- 034-3-535-77 (TAC)) (Bloomington, IN: Indiana University, 1979).

⁵¹ Ibid.

Overall, the literature is weak with regard to the temporal distribution of catastrophes related to public health and safety.⁵² In a study of the nuclear power industry, Mitler et al. examined human error catastrophes in an effort to correlate physiology, alertness, and the time of day to a recorded catastrophe.⁵³ They argued that the unlikely possibility that four of the world's most notable nuclear disasters and near disasters could have occurred by chance during night shifts or times nuclear center on-duty staff's natural circadian rhythms would have them sleeping. Mitler et al. examined the following well-known disasters:

- Middletown, Pennsylvania; "Three Mile Island"; March 28, 1979; 4:00 a.m.
- Oak Harbor, Ohio; Davis-Besse; June 9, 1985; 1:35 a.m.
- Sacramento, California; Rancho Seco Nuclear Reactor; December 26, 1985; 4:14 a.m.
- Ukraine, Chernobyl; April 26, 1986; 1:23 a.m.

Carskadon et al. pointed out the likelihood that given the timing of the four major disasters, fatigue may have played a role. They further examined other data sets as well involving 75,000 meter readings and notable accidents in the nuclear energy industry. Carskadon et al. identified error patterns similar to the bimodal patterns observed in car accidents and medical incidents, which showed a primary peak time for human error accidents of between midnight and 7:00 a.m., and a second, less pronounced spike between 1:00 and 4:00 p.m. While the temporal distribution of performance errors was identified, the study did not document a direct cause and effect relationship between sleep related issues or fatigue and catastrophes. Still, the study did show a relationship between the timing of catastrophic incidents and key brain functions associated with sleep. This pioneering study represents an early and important contribution to the literature on the potential detrimental effects of fatigue in high consequence work environments.⁵⁴

⁵² Mary A. Carskadon et al., *Catastrophes, Sleep, and Public Policy* (Emmitsburg, MD: National Emergency Training Center, 1988).

⁵³ Ibid.

⁵⁴ Ibid.

In 2008, Sovacool set out to assess the causes of major energy accidents, and although his study did not address fatigue directly, it provides perspective on the Carskadon et al. examination of the four abovementioned nuclear catastrophes. Sovacool analyzed accidents that occurred within the energy generation plant between 1907 and 2007 that resulted in at least one death or damage above \$50,000 (adjusted to 2006 U.S. dollars). Any included incidents must have been non-military and unintentional, and after excluding those that did not meet the criteria, a total of 279 major energy accidents, which included 63 nuclear ones, were itemized. Sovacool's study contributed to the literature by demonstrating a commonality between accidents and the devastating toll they take on public safety and the environment despite the technological and procedural improvements over a 100-year period. His work suggests that human error is a probable culprit in disasters since substantial technological advances have seemingly not helped the highly regulated nuclear industry avoid frequent accidents.⁵⁵

While research on the relationship of fatigue to serious human error has been documented in the nuclear industry, research is more limited for police work, which recently became identified as a high-consequence occupation. Virtually all studies specific to field police work discuss the hazards associated with fatigued police officers,⁵⁶ and fail to address expanded homeland security roles taken on by those in the police forces. Instead, they focus on traditionally high-consequence tasks, such as driving emergency vehicles and decisions to use deadly force. A recent study by Violanti considered the impact of shift work on two groups of police officers and focused on determining whether a nexus existed between irregular sleep (and therefore, fatigue) and the overall well-being of police officers. The findings indicated that irregular sleep and fatigue among police officers were correlated with degraded levels of overall health and well-being, suggesting that fatigue due to irregular sleep impacted their ability to be at

⁵⁵ Benjamin K. Sovacool, "The Costs of Failure: A Preliminary Assessment of Major Energy Accidents, 1907–2007," *Energy Policy* 36, no. 5 (2008): 1802–1820, doi: 10.1016/j.enpol.2008.01.040.

⁵⁶ Dennis Jay Kenney and Bryan Vila, *Tired Cops: The Prevalence and Potential Consequences of Police Fatigue* (Washington, DC: National Institute of Justice, 2002), <https://www.ncjrs.gov/pdffiles1/jr000248d.pdf>; Lauren B. Waggoner, "Police Officer Fatigue: The Effects of Consecutive Night Shift Work on Police Officer Performance" (PhD diss., Washington State University, 2012).

peak performance while working. The credibility of the study was enhanced by a strong design, including large sample populations and control groups.⁵⁷

In 2002, Dennis Jay Kenney and Bryan Vila studied four mid-sized police departments to help determine how officer wellness and performance were affected by fatigue and to identify the major contributors to fatigue in a field police work setting.⁵⁸ Although located in different parts of the United States, the agencies were selected for their similarities in sworn strength, size of population served, calls for service, and diverse work schedules. Kenny and Vila collected a range of personnel data, including the total number of hours worked by each officer, changes in work schedules, and duty-related injuries and accidents. Individual officers also consented to using an electronic device that measured sleepiness at the beginning of each workday and each completed the Pittsburgh Sleep Quality Index, which is a validated testing instrument used to help diagnose sleep disorders. The results indicated that the officers from the two police departments that used compressed work shifts reported significantly less fatigue during the first few hours of any given shift and fewer problems falling and staying asleep compared to those officers with longer weeks and shorter work shifts. The findings also revealed a correlation between coping with fatigue and age, which suggested that with increasing age, officers were more negatively impacted by fatigue and sleep disruption. Further, police departments that allowed tenured officers to select their shift of preference had officers with lower levels of sleepiness and fatigue. In contrast, departments deploying officers based solely on the needs of the agency had officers with higher levels of fatigue, especially among older officers. Further, impactful factors other than age were noted, as having young children in the home was cited as a significant contributor to fatigue and sleep disruption. Although the findings of this study were not specific to command center police work, they are relevant to it. Kenny and Vila is the first study to

⁵⁷ John Violanti, *Shifts, Extended Work Hours, and Fatigue: An Assessment of Health and Personal Risks for Police Officers* (Washington, DC: National Institute of Justice, 2016), 2, <https://www.ncjrs.gov/pdffiles1/nij/grants/237964.pdf>. Note: 464 officers of the Buffalo Police Department participated in the study. The mortality group consisted of 1,035 deceased Buffalo police officers.

⁵⁸ Kenney and Vila, *Tired Cops: The Prevalence and Potential Consequences of Police Fatigue*.

demonstrate that officers fall prey to fatigue, and that increasing age, having young children at home, and working non-preferred shifts makes them more vulnerable.⁵⁹

The Kenney and Vila study, like most others in the literature, use self-report methods to measure fatigue, yet evidence exists that the experience of fatigue is often underreported in self-assessments. Credible research by Cebola and Kilner demonstrated that fatigued study subjects are unreliable at assessing their own level of fatigue, which suggests that studies utilizing self-report methods may fail to capture actual fatigue.⁶⁰ The Shift Length Experiment by Anneke Heitmann et al. confirmed that under-reporting of fatigue is common among officers, and indicated that “the willingness of officers to report fatigue may also be somewhat repressed by the police culture, which promotes toughness.”⁶¹ Hence, police officers may have clear reasons for not reporting an honest assessment of their fatigue levels, a point deserving close consideration by public safety agencies and in future research. Regarding the latter, in the Vila study, underreporting of fatigue was likely evident given that “officers who worked 10- and 12- hour shifts for fewer days repeatedly emphasized that such shifts were less fatiguing.”⁶²

The Amendola et al. study not only highlighted the problem of underreporting, it also provided significant evidence of the negative impacts of fatigue by utilizing several validated testing instruments, including driving simulators, deadly force decision simulators, and questionnaires.⁶³ In their Shift Length Experiment, two police departments from Detroit, Michigan and Arlington, Texas were selected because of their

⁵⁹ Kenney and Vila, *Tired Cops: The Prevalence and Potential Consequences of Police Fatigue*.

⁶⁰ Andrew Kilner and Nuno Cebola, *When Are You Too Tired to Be Safe? Exploring the Construction of a Fatigue Index in the ATM* (Lisbon: Lisbon University Institute, 2009), [https://eurocontrol.int/eec/gallery/content/public/document/other/conference/2009/safety_r_and_d_Munich/day_2/Andy-Kilner-\(EUROCONTROL\)-Paper.pdf](https://eurocontrol.int/eec/gallery/content/public/document/other/conference/2009/safety_r_and_d_Munich/day_2/Andy-Kilner-(EUROCONTROL)-Paper.pdf).

⁶¹ Anneke Heitmann et al., *The Shift Length Experiment: What We Know About 8-, 10-, and 12-Hour Shifts in Policing* (Washington, DC: Police Foundation, 2011), 35–36, https://www.policefoundation.org/wp-content/uploads/2015/06/ShiftLengthExperiment_0.pdf.

⁶² Kenney and Vila, *Tired Cops: The Prevalence and Potential Consequences of Police Fatigue*, 18. Note: In this study, the authors could not test how officers on compressed shifts compared with those on regular 8-hour shifts within the same agency. Thus, it is not known if it was compressed shifts that caused less fatigue or some other factors associated with departments themselves.

⁶³ Karen Amendola et al., *The Impact of Shift Length in Policing on Performance, Health, Quality of Life, Sleep, Fatigue, and Extra-Duty Employment* (Washington, DC: National Institute of Justice, 2012), 39, <https://www.ncjrs.gov/pdffiles1/nij/grants/237330.pdf>.

large size and the agencies' interest in examining the advantages and disadvantages of moving away from a traditional 8-hour shift. To protect the integrity of the experiment, only officers assigned to unrestricted (not light or part-time) patrol duties participated. They fully consented to volunteer for the study and agreed to be assigned to one of three shifts lengths (i.e., eight, 10, or 12 hours). Despite the participation requirement that required officers to accept random shift assignments and set aside their usual or preferred shift or schedule, 326 volunteered across both sites. Participants were randomly and evenly assigned to one of the three watch conditions (109, 109, and 108, respectively).

The results of the study identified notable negative effects of fatigue on work performance. Officers assigned to work the longest shifts in the study (e.g., 12 hours) reported more that they were sleepy and lacked alertness significantly more than officers working the shortest of the shifts (e.g., eight hours). No significant disparity was noted between subject groups working 8-hour and 10-hour shifts. It appeared that officers on the 10-hour shift acquired adequate sleep time, and accordingly, were generally as alert as those working 8-hour shifts. Amendola et al.'s study provided support for the negative impacts of fatigue in police work. Given the known biases inherent to self-reporting and the determination by the authors that some officers were advocating to move away from a traditional work week and toward a compressed one, it is likely that the study's findings would have been stronger if it employed a more objective measure of fatigue and a sample of police officers not advocating for working fewer days with longer shifts.

Although limited studies have examined fatigue in line-level law enforcement, the literature specific to the HSE in general, and to the technology-rich environments of public safety career fields, is even more minimal. One notable exception is a 2008 study by Basner et al. that focused on Transportation Security Administration (TSA) baggage screeners. Basner et al. measured the accuracy of security screeners in relation to two variables, level of fatigue and time-on-task. Of particular note is that the participants were not actually baggage screeners, but instead, were volunteer test subjects. The simulation required subjects to detect an x-ray image of a gun or knife on a video monitor with varying degrees of difficulty. Evidence of a gun or knife was present in 25 percent of the video simulation images, a percentage rate that far exceeded that encountered by

actual baggage screeners. Despite the unrealistic nature of this experiment and its small sample size of 24, it demonstrated a strong correlation between error rates and the fatigue that results from an extended time-on-task.⁶⁴

Several related studies on the impact of fatigue have been conducted with military personnel. In one fairly recent military study by Harville, Harrison, and Chaiken using United States Air Force (USAF) officers, 22 male and eight female volunteer subjects participated in vigilance tests after 36 hours of sleep deprivation. Prior to the sleep deprivation, the subjects were trained to use a command and control simulation system,⁶⁵ and following the sleep deprivation period, a well-established video-based math processing and memory-testing instrument was used to measure the presence and level of fatigue.⁶⁶ Also, a personal history questionnaire was used to establish participants' history with sleep deprivation, which included assessing prior life experience staying up all or half of the night (excluding times when caffeine was used and wakefulness caused by illness).⁶⁷ As expected, extended periods of wakefulness had a detrimental effect on performance, and a significant correlation occurred between staying up all night or half nights and the degree to which fatigue degrades performance, with higher experiences associated with higher performance degradation. The Harville et al. study is particularly relevant because it involves USAF officers who selected for and were awaiting training to be Airborne Warning and Control System (AWACS) operators, which is essentially a flying command center work environment.

Jeff Whitmore et al. conducted a subsequent USAF sleep deprivation study with the same USAF laboratory used in the 2006 Harville et al. investigation. As in the previous study, participants numbered 22 males and eight females, all active duty USAF

⁶⁴ Mathias Basner et al., *Fatigue and Threat Detection*, 1st ed. (Philadelphia: University of Pennsylvania School of Medicine, 2008), <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2542965/pdf/aasm.31.9.1251.pdf>.

⁶⁵ Donald Harville, Richard Harrison, and Chaiken Scott, *The Fatigue Equivalent of Job Experience and Performance in Sustained Operations* (Fort Belvoir, VA: Defense Technical Information Center, 2006), 4. Note: C3STARS is the name of the system and it stands for Command, Control, Communications, Simulation, Training and Research System.

⁶⁶ Ibid. Note: This instrument is the automated neuropsychological assessment metric.

⁶⁷ Harville, Harrison, and Scott, *The Fatigue Equivalent of Job Experience and Performance in Sustained Operation*, 4, Appendix A.

officers who were placed in teams defined as “two or more individuals working toward a common goal in an interdependent fashion.” This study examined teams engaged in tasks ranging from the esoteric (e.g., battle management) to the every-day tasks (e.g., administrative functions in offices),⁶⁸ reflecting common tasks of military and civilian occupations conducted in the interest of public safety at all times of day or night (e.g., power plant operations) and after extended work periods (e.g., emergency medical surgery). The methodology was similar to that of the previous study, as it included the administration of a series of psychomotor and cognitive tasks, although in this study, each participant’s performance was measured while performing both individual work and three-person team tasks. Harville et al. determined a significant relationship between fatigue and low work performance, although the relationship was weaker for teamwork compared to its relationship to individual performance. The researchers noted that team tasks tended to be different from individual tasks, and more importantly, the team dynamic could be responsible for the differences in fatigue effects. The latter suggests that working in teams may be an important consideration for command centers to consider in mitigating fatigue. It is also suggestive of the multi-dimensional nature of fatigue and the complex manipulations that can be made to enhance performance. Among the first researchers to consider the complexities of achieving peak performance, they earned a name for themselves in history.

The Yerkes-Dodson Law appears sporadically throughout the literature on human fatigue, and the status of “law” reflects Robert M. Yerkes and John D. Dodson’s prominent place in virtually all introductory psychology textbooks and in scholarly writers’ continual challenges to the universality of a law that has evolved beyond its original scope.⁶⁹ The correlation between the strength of a stimulus and the time needed

⁶⁸ Jeff Whitmore et al., *Sleep Loss and Complex Team Performance* (Ft. Belvoir: Defense Technical Information Center, 2008), 1.

⁶⁹ Peter A. Hancock and H. C. Neil Ganey, “From the Inverted-U to the Extended-U: The Evolution of a Law of Psychology,” *Journal of Human Performance in Extreme Environments* 7, no. 1 (2003): 5, doi: 10.7771/2327-2937.1023.

to learn was the primary focus of their simplistic 1908 experiment.⁷⁰ While the iconic “inverted U” in Figure 1 does not appear in the original 1908 research, and despite its recent detractors, many researchers find it useful to conceptualize conditions for optimal performance.⁷¹ Using only four mice and three trials, Yerkes and Dodson concluded that increases in the strength of a stimulus corresponded to decreases in the time taken to learn a new task. Specifically, mice received varying jolts of electricity for failing to discriminate between the correct and incorrect paths that were visibly different (i.e., white and black, respectively),⁷² and performance improved with increasing electricity, but only to the point that the electricity would begin to harm the mice.⁷³

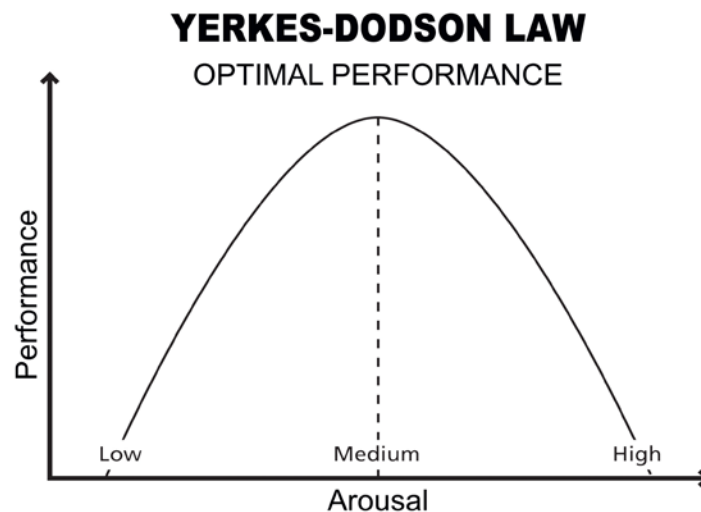


Figure 1. Yerkes and Dodson’s 1908 Study Results.⁷⁴

⁷⁰ Robert M. Yerkes and John D. Dodson, “The Relation of Strength of Stimulus to Rapidity of Habit-Formation,” *Journal of Comparative Neurology and Psychology* 18, no. 5 (1908): 459–482, doi: 10.1002/cne.920180503.

⁷¹ Mark Staal, *Stress, Cognition, and Human Performance: A Literature Review and Conceptual Framework* (Moffett Field, CA: National Aeronautics and Space Administration, Ames Research Center, 2004), 4, https://human-factors.arc.nasa.gov/flightcognition/Publications/IH_054_Staal.pdf.

⁷² Ibid.

⁷³ Ibid. Note: Yerkes and Dodson did not desire harm their mice; they surmised that performance would drop off if the shocks were to become harmful.

⁷⁴ Adapted from Staal, *Stress, Cognition, and Human Performance: A Literature Review and Conceptual Framework*, 4.

Mention of the law is often accompanied by a variation of an inverted “U” graphic used to demonstrate that optimal performance is more likely to occur when an optimal stimulus results (i.e., not too much and not too little). The inverted “U” and its variations have far-reaching implications for high consequence work environments, or any work environment wherein peak performance is important. The model suggests that human fatigue is naturally occurring and inevitable, and research based on it provides evidence that fatigue and fatigue-like states, including those brought about by monotony or boredom can be mitigated by an arousal-inducing stimulus and workplace design.⁷⁵

Hopstaken et al. provided empirical evidence of the classic “inverted ‘U’” of the Yerkes-Dodson Law by attempting to demonstrate that moderate arousal promotes optimal engagement and performance in humans. They used three measures of mental fatigue: self-reports, performance, and psychophysiological measurement. Mental fatigue was defined as “a complex state characterized by reluctance for further effort and changes in mood, motivation, and information processing.”⁷⁶ Twenty undergraduate students who served as the subjects completed the self-report surveys and a total of seven cognitively-taxing blocks while being electronically monitored for physiological fatigue levels. After the sixth block, the subjects were given a reward manipulation, which they believed allowed them to leave the study much sooner if they were able to complete the task at a faster rate.⁷⁷ Hence, the research was carefully designed to induce fatigue and then to arouse recovery.

Hopstaken et al. reported increased mental fatigue over time and increments in task disengagement in the pre-reward manipulations (i.e., blocks 1–6), and following the

⁷⁵ Gerald Matthews, *Levels of Transaction: A Cognitive Science Framework for Operator Stress* (Dundee, Scotland: ResearchGate, 2001), https://www.researchgate.net/profile/Gerald_Matthews2/publication/284577742_Levels_of_transaction_a_cognitive_sciences_framework_for_operator_stress_in_Stress_Workload_and_Fatigue/links/57c9dd9708ae59825180f5a3; P. A. LeDuc, J. A. Caldwell and P. S. Ruyak, *The Effects of Exercise Versus Napping on Alertness and Mood in Sleep-Deprived Aviators* (Fort Rucker, AL: U.S. Aeromedical Research Laboratory, 2000), <http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.459.2378&rep=rep1&type=pdf>.

⁷⁶ Jesper F. Hopstaken et al., “A Multifaceted Investigation of the Link between Mental Fatigue and Task Disengagement,” *Psychophysiol* 52, no. 3 (2014): 305, doi: 10.1111/psyp.12339.

⁷⁷ Ibid. Note: There was no actual reward or punishment phase; block no. 7 was the same length as block nos. 1–6.

reward manipulation (i.e., block 7), subjects reported reduced fatigue and increased task engagement, which suggests that the reward manipulation markedly improved performance. The data for physiological measures of performance and task engagement were similar to the objective performance data patterns, and accordingly, the study provided strong empirical support for the detrimental effects of fatigue and their ability to be reversed.⁷⁸ However, the authors theorized that task disengagement might mimic a fatigue-like state, while its purpose was to prevent a depletion of resources.⁷⁹

This research is important to high consequence work environments because it reaffirmed that fatigue is multidimensional, existing in realms of the physical and metaphysical, and tends to increase with time, yet can be manipulated without rest. One limitation in the applicability of the study to high-consequence work environments is the relatively brief period in which performance following high fatigue could be improved. That minimal amount of time may not be particularly helpful to real world HSE command centers, where officers work eight hours or more per shift. Hence, the rebound of arousal following fatigue seems to be relatively short-lived, reflecting what would be a small percentage of the overall work period in command centers. In short, within the framework of the Yerkes-Dodson Law, and evident in the literature, sustained arousal is complex and ultimately leads to a loss in performance. This law, along with the Hopstaken et al. study, are useful tools in considering fatigue mitigation, and form some of the foundation for a range of methods for reducing the effects of fatigue, including those involved in workplace design outlined by Gaillard (2003).⁸⁰ His design elements and other types of recommendations for addressing fatigue in HSE command centers are presented in Chapter VI.

⁷⁸ Hopstaken et al., “A Multifaceted Investigation of the Link between Mental Fatigue and Task Disengagement,” 313.

⁷⁹ Ibid.

⁸⁰ Robert Hockey, Anthony W. K. Gaillard, and Oleksandr Burov, *Operator Functional State* (Amsterdam: IOS Press, 2003), 24–35.

C. CONCLUSION

The depth of the literature on fatigue seems to correspond to the volume of failures, the seriousness of the associated catastrophes, and the importance that future incidents be mitigated in the interest of public safety. Accordingly, in fields vulnerable to fatigue and related failures and catastrophes, the volume of research is especially rich. For these reasons, emergency medicine, transportation, and energy production dominate the fatigue-related human factors research. The pervasive risks to public safety have resulted in a societal mandate to investigate major adverse incidents, especially those that repeat themselves throughout history.

Understanding fatigue for the purpose of mitigating its effects and improving efficiency, productivity, or employee wellness is the prevailing theme in the current body of research on fatigue. The relevance of metal and soil fatigue, when compared to the greater body of work that includes human performance, is clarified when failures are viewed in terms of high- and low-consequence events. It was the high-consequence failures in metals that were the catalyst to better detection, prevention, and mitigation protocols. Today, fatigue in living and non-living things still occurs, but in catastrophic incidents, fault must now be shared with humans who may have exceeded known capacities. In the realm of human performance and wellbeing, there is interest in both the high-consequence and the low-consequence fatigue related events, but as expected, more extensive research has been conducted on high-consequence events and environments. Whether high-consequence or low, human or non-human, fatigue is an adversary to be detected, managed, and its effects mitigated, but not one that can be defeated. Today's society is irrevocably dependent on risky activities, such as energy production and rapid transit, and these risky activities require systems in which humans must interface with technology. While fatigue is not an entity with intelligence or strength of its own, it can infiltrate systems and degrade performance. In this context, attributing fault to one single cause, especially in activities dependent on human performance, is difficult and not rational.

Complicating matters further, the literature provides evidence that living things bring naturally occurring circadian rhythms to the equation. Long-term and large sample

studies of human error and catastrophes demonstrate that while adverse events can occur at any time during the day or night, over extended periods of time, predictable spikes can correspond to the rhythms associated with non-optimal performance. Critical operations in a public safety context cannot always be scheduled during periods of optimal human performance, but knowing periods when human performance errors are more likely to occur can contribute to better supervision and other policies and procedures that will decrease the likelihood of human error.

Research suggests that avoiding fatigue in high-consequence environments is complicated by research findings that indicate circadian rhythms can vary from individual to individual, which implies procedures and guidelines should account for individual differences. Human beings, perhaps more than other living things, add additional complexities to the study of fatigue and human performance. Beyond individual differences, tolerances, and thresholds, human beings assimilate into cultures and associations. In a couple of studies, researchers found that working in teams provided some insulation from individual error. Studies of fatigue involving the military were of particular interest because the participants are generally not allowed to be a part of labor unions and to advocate for the same rights and privileges for all members. Conversely, research involving police agencies generally includes disclaimers for the biases related to collective bargaining rights. However, studies show that providing faulty information is not always the product of an intentional bias; the research indicates that people often are unable to self-assess their level of fatigue accurately, which calls into question workplace environments that rely on the self-reporting of fatigue levels. Some of the issues involved in poor self-report reliability may be related to workplace culture, particularly in the public safety sector. Military and police studies in particular deal with a culture of bravery, not unexpected given these two career fields employ people who accept certain elements of risk as a condition of employment. Three kinds of anticipated risks that military and HSE personnel accept are unique from other high-consequence occupations given that they commonly involve an intentional and intelligent adversary.

Ultimately, the literature on human performance and fatigue is rich, yet notable gaps occur with regard to the latent effects of organized culture and policies, particularly

concerning policing and homeland security. The most compelling studies, which are fairly recent ones, suggest that fatigue is associated with longer work shifts, particularly night ones, monotonous tasks, poorer cognitive and emotional processing, a range of performance issues, particularly for older employees or those who have young children at home (who may disrupt sleep), and in some fields, catastrophes. In the area of sleep deprivation and high-consequence occupations, considerable research studies exist to show the damaging effects of a lack of sleep, resulting in changes in policy in some fields. In particular, updated regulations are now in place for pilots, air traffic controllers, and commercial truck drivers, but not for police officers and others working in HSE command centers.

Unfortunately, with respect to police work, a gap exists in fatigue research on non-patrol assignments, such as those in the HSE command center environment, which may be attributable to the relatively short time that the HSE has been in existence. This lack of research is especially important to note given recently introduced job duties in command center environments, such as monitoring video camera feeds and other functions wherein signals (e.g., indicators of a risk to public safety such as clues, trends, and alarms) are monitored, analyzed, and disseminated for action, and in which work can be monotonous. Fortunately, these types of command center developments are found in the aviation and nuclear power industries, which have policies in place to address fatigue. Hence, the following two chapters provide a comparative analysis of fatigue research and findings in air traffic control and the nuclear power industry command centers.

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III. COMPARISON GROUP ONE—AIR TRAFFIC CONTROL

My mind clicks off, as though attached to an electric switch with which some outside force is tapering. I try letting one eyelid close at a time while I prop the other open with my will. But the effort's too much. Sleep is winning. My whole body argues dully that nothing, nothing life can attain, is quite so desirable as sleep.

~ Charles A. Lindbergh, referring to fatigue during his first transatlantic flight⁸¹

A. BACKGROUND

Early aviation had little to do with safety; it was about adventure, risk, and understanding the laws of physics. Since manned flight began nearly a century ago, aviation's landscape has been littered with crashes.⁸² In consideration of the balance of mechanical failure in relation to human error, the first aviators were more likely to have been killed through a mechanical failure of their flying machines. As flying technologies progressed, human failure surpassed mechanical failure as the primary cause for aviation catastrophes. Among the earliest mitigating injects for aviation safety was the air traffic controller.

The very first air traffic controller (ATC) was responsible for communicating with pilots to avoid collisions and to improve the chances of a successful landing. With a low-tech windsock and two flags, the first ATC communicated vital collision avoidance information to the pilots.⁸³ A properly placed windsock communicated the wind direction at and near the airfield, which previously had been a tenuous assessment for the pilot. Before dedicated airfields were the norm, landings and takeoffs were made on any open and reasonably flat parcel of land, such as pastures and fair grounds. The wave of a checkered flag communicated to the pilot that it was safe to proceed, while a red flag

⁸¹ Charles A. Lindbergh, *The Spirit of St. Louis* (New York: Scribner, 1953), 220.

⁸² Scott A. Shappel and Douglas A. Wiegmann, *The Human Factors Analysis and Classification System—HFACS* (Washington, DC: U.S. Federal Aviation Administration, Office of Aviation Medicine, 2000).

⁸³ Embry-Riddle Aeronautical University, Prescott Aviation History Program, "The History of Air Traffic Control," video, 2012, <http://commons.erau.edu/aviation-history/9/>. Note: 10 Minute Timemark: Archie League of St. Louis Missouri is widely accepted as the first air traffic controller.

warned them to stop or to go around.⁸⁴ The confluence of aircraft at a landing field made the ground more dangerous than the air. Avoiding mid-air collisions was the responsibility of the individual pilots. It was the landings and the take-offs that posed the greatest threat for collisions.

By 1921, aviation was showing great promise for military applications, but it was aviation's value to the economy that was the real catalyst for building reliability and safety into the system. The United States Postal Service (USPS) designated the first transcontinental airway route, along which it established the first Air Mail Radio System (AMRS). In 1926, the Air Commerce Act briefly gave the responsibilities for air traffic and the AMRS to the Bureau of Lighthouses under the Department of Commerce.⁸⁵ By the end of the 1920s, aviation and approximately 145 municipally-owned airfields had dedicated frequencies. A dedicated agency known as the Airways Division was responsible for the steadily improving radio system, which was renamed the Air Radio System (ARS).⁸⁶

The first radio-equipped control tower was built in Cleveland in 1930. By about 1932, almost all major carriers used radio-equipped aircraft and 20 radio-equipped control towers were located across the country. In December 1935, the first air traffic control "center" was established as a cooperative effort between the commercial airlines flying routes between the cities of Chicago, Cleveland, and Newark. Collision avoidance was accomplished through the use of initial flight plans, which were kept current based on radio updates from the flight crew. In 1936, the federal government assumed responsibility for the air traffic control centers, and by 1944, air traffic controllers totaled 115.⁸⁷ The arrival of radar in 1952 held great promise for a variety of civil and military applications; however, in 1956, radar still was not widely used for collision avoidance. In

⁸⁴ Embry-Riddle Aeronautical University, Prescott Aviation History Program, "The History of Air Traffic Control."

⁸⁵ Ibid.

⁸⁶ Ibid.

⁸⁷ Ibid.

1956, an air traffic controller and two pilots, operating within the work rules of the day, were part of a catastrophic incident that accelerated change in aviation.⁸⁸

B. CATALYST FOR CHANGE IN AVIATION

On the morning of June 30, 1956, two modern aircraft by the standards of the day took off from Los Angeles International Airport less than three minutes apart from one another. The Trans World Airline L-1049 Super Constellation was en route to Kansas City and a United Airlines DC-7, Flight 718, was destined for Chicago. Within a safe margin, the aircraft were to intersect paths over the Grand Canyon, Arizona. At 10:31 a.m., at 21,000 over the Grand Canyon, a catastrophic mid-air collision occurred.⁸⁹ Moments before, an air traffic controller (Salt Lake City) had logged the latest positions of the involved aircraft. He was fully aware that both planes were converging at 21,000 feet, and that they would be over an area known as the Painted Desert at about the same time, but he was not required to make notifications because the pilots were flying under visual flight rules. Visual flight rules are established by the FAA and specify the amount of unassisted visibility the pilot must have to conform to the premise of “see and be seen.”⁹⁰ During a public hearing, the involved controller testified that he was “not required to give advisory information to flights that were in uncontrolled airspace and that such advisory information would have been only a discretionary duty in controlled areas.”⁹¹ In controlled airspace, air traffic controllers provide service, while in uncontrolled airspace, pilots operate under visual flight rules.⁹²

⁸⁸ Jon Proctor, “Lessons from Tragedy over the Grand Canyon,” TWA Seniors Club, updated September 18, 2016, <http://www.twaseniorsclub.org/memories/contrails/tragedygrandcanyonTW-UA.html>.

⁸⁹ Civil Aeronautics Board, *TWA—UAL Accident Investigation Report Grand Canyon Arizona* (Washington, DC: Civil Aeronautics Board, 1957), http://lessonslearned.faa.gov/UAL718/CAB_accident_report.pdf.

⁹⁰ Federal Aviation Administration, *Risk Management Handbook* (Washington, DC: U.S. Department of Transportation, 2009), https://www.faa.gov/regulations_policies/handbooks_manuals/aviation/media/faa-h-8083-2.pdf; Federal Aviation Administration, *VFR Weather Minimums* (Washington, DC: Federal Aviation Administration, n.d.), accessed December 7, 2016, <https://www.faa.gov/files/gslac/courses/content/25/185/VFR%20Weather%20Minimums.pdf>.

⁹¹ *Ibid.*, 10.

⁹² Federal Aviation Administration, *Pilot’s Handbook of Aeronautical Knowledge 2016* (Newcastle, WA: Aviation Supplies & Academics, 2016), 14.2.

The Director of the Civil Aeronautics Administration corroborated the controller's testimony when he said that "it was not the policy or the concept of Air Traffic Control to provide traffic information outside of controlled airspace."⁹³ He added that giving advice in uncontrolled airspace would be tantamount to "positive control" in all space,⁹⁴ an air traffic control term used to indicate controllers are responsible for actively separating every airborne aircraft from each and all other ones. One week after the report became public, the federal government announced a plan to provide "positive control" of all aircraft flying above designated altitudes regardless of weather conditions.⁹⁵ Weather conditions were specifically included as non-exempt from positive control as a result of the 1956 Grand Canyon disaster that occurred in near perfect weather conditions, a situation for which, at that time, visual flight rules had been deemed adequate.⁹⁶ The Federal Aviation Act of 1958 established the FAA and gave it statutory control of airspace within the United States. With that authority, the FAA then created the National Airspace System (NAS) with the stated purpose "to protect persons and property on the ground and to establish a safe and efficient airspace environment for civil, commercial, and military aviation."⁹⁷

The work of air traffic controllers is credited for making commercial aviation among the safest modes of travel in the world.⁹⁸ Air traffic controllers work in the Air Traffic Organization (ATO), which is the operational component of the FAA. In cooperation with the National Air Traffic Controller Association (NATCA), the ATO provides navigation services to the pilots operating within 30.2 million square miles of

⁹³ Civil Aeronautics Board, *TWA—UAL Accident Investigation Report Grand Canyon Arizona*, 11.

⁹⁴ *Ibid.*

⁹⁵ Proctor, "Lessons from Tragedy over the Grand Canyon."

⁹⁶ *Ibid.*

⁹⁷ Federal Aviation Administration, *National Airspace System Overview* (Washington, DC: Federal Aviation Administration, 2016), 2, https://www.faa.gov/air_traffic/nas/nynjphl_redesign/documentation/feis/media/Appendix_A-National_Airspace_System_Overview.pdf.

⁹⁸ Federal Aviation Administration, *FAA's Controller Scheduling Practices Can Impact Human Fatigue, Controller Performance, and Agency Costs* (Report Number: AV-2013-120) (Washington, DC: Federal Aviation Administration, 2013), <https://www.oig.dot.gov/sites/default/files/FAA%20Air%20Traffic%20Controller%20Scheduling%20Practices%5E08-27-13.pdf>.

airspace, including all of the United States and major portions of both the Atlantic and Pacific Oceans.⁹⁹

C. AIR TRAFFIC CONTROLLER FATIGUE

Air traffic control generally requires shift work, which means that many air traffic controllers work at times when they would ideally be asleep. In addition, controller schedules frequently change to adapt to the operational needs of facilities, which often operate 24 hours a day, and can lead to fatigue. Some air traffic control workstations are staffed around the clock, while others are not. The focus of this comparative analysis is on air traffic controller operations open 24-hours per day, seven days per week, and 365 days per year.

The FAA has long recognized the detrimental effects that fatigue has on ATC performance. The workplace policies for air traffic controllers in the United States are set locally with the participation of the ATC union (NATCA), and must conform to the regulations set forth by the FAA and ATO. NATCA also publishes the collective bargaining agreement (CBA), a document referred to among air traffic controllers and the NATCA as “the redbook.”¹⁰⁰ It is the most updated and comprehensive version of the labor contract and applicable revisions existing between air traffic controllers and the FAA. CBA policies permit local facility managers to work with NATCA representatives to negotiate a basic watch schedule annually. The “basic watch schedule” refers to the baseline shifts (e.g., days, hours, and rotation of shifts) that can be altered by managers to establish facility-specific practices that may be outside of the basic schedule to meet labor needs at the local level. Ultimately, the CBA is permissive, allowing schedules to evolve locally and reflect local conditions. As such, the actual schedules may not conform to the national policy and may not reflect the current state of knowledge for

⁹⁹ Federal Aviation Administration, *FAA’s Controller Scheduling Practices Can Impact Human Fatigue, Controller Performance, and Agency Costs*.

¹⁰⁰ This contract was in force from 2009 to 2016. Federal Aviation Administration, *Collective Bargaining Agreement between the National Air Traffic Controllers Association AFL-CIO and the Federal Aviation Administration U.S. Department of Transportation October 2009* (Washington, DC: Federal Aviation Administration, 2009).

fatigue management.¹⁰¹ Under these permissive guidelines, operational needs and workforce preferences at each air traffic facility could dictate the actual scheduling process. For example, the counterclockwise rotating 2-2-1 schedule is popular among controllers,¹⁰² serving as a coveted schedule that condenses a traditional five-day workweek into four days, followed by 80-hours off duty.¹⁰³ Reviews of the practice from a fatigue and safety perspective have found it questionable; yet, it is often permitted within the broad boundaries of the guidelines.

The work schedule depicted in Figure 2 further highlights this problem. The schedule requires a controller to work two swing shifts, two day shifts, and a midnight shift within the same week. The time off for commuting and resting between each of the second, third, fourth, and fifth shifts is particularly short. As a consequence, the schedule's compatibility with circadian rhythms and adequate recuperative sleep is unlikely; thereby, increasing the risk for fatigue and related accidents.¹⁰⁴

¹⁰¹ Jill Wilson and Mark Hutchins, *The Federal Aviation Administration's Approach for Determining Future Air Traffic Controller Staffing Needs* (Special Report No. 314) (Washington, DC: National Academies Press, 2015), 72–73, <http://onlinepubs.trb.org/onlinepubs/sr/sr314.pdf>.

¹⁰² Ibid., ch. 2: Aviation Safety and Controller Staffing, 39.

¹⁰³ Ibid.

¹⁰⁴ Ibid.

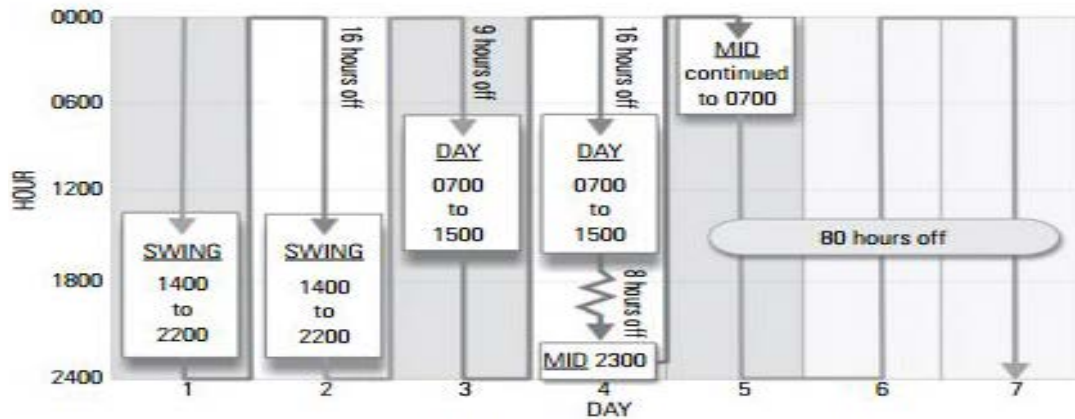


Figure 2. Example of Counterclockwise Rotating 2-2-1 Schedule.¹⁰⁵

In August 2013, the United States Department of Transportation’s Office of the Inspector General released its audit findings to the FAA.¹⁰⁶ After close examination of human errors through a careful examination of records, the report titled, *FAA’s Controller Scheduling Practices Can Impact Human Fatigue, Controller Performance, and Agency Costs*, was generated as a mandate of the FAA Modernization and Reform Act of 2012.¹⁰⁷ Several of the audit’s objectives were highly relevant to this thesis, especially the identification of the impact of scheduling practices on safety and performance.¹⁰⁸ It included a detailed examination of a total of 32,814 of an estimated 599,749 total work shifts¹⁰⁹ of 403 of the 2,184 certified professional controllers (CPCs) over a brief three-month period between April 8, 2012 and July 28, 2012.¹¹⁰ A sophisticated four-stage stratified probability proportional to size sample helped to ensure that the results would allow the audit to project the total percentage of controller work

¹⁰⁵ Source: Wilson and Hutchins, *The Federal Aviation Administration’s Approach for Determining Future Air Traffic Controller Staffing Needs*, 38.

¹⁰⁶ Federal Aviation Administration, *FAA’s Controller Scheduling Practices Can Impact Human Fatigue, Controller Performance, and Agency Costs*, 1–30.

¹⁰⁷ Congress, *Pub. L. No. 112-95—FAA Modernization and Reform Act of 2012* (Washington, DC: Government Printing Office, 2012), <https://www.gpo.gov/fdsys/pkg/PLAW-112publ95/pdf/PLAW-112publ95.pdf>.

¹⁰⁸ Federal Aviation Administration, *FAA’s Controller Scheduling Practices Can Impact Human Fatigue, Controller Performance, and Agency Costs*, 1.

¹⁰⁹ *Ibid.*

¹¹⁰ *Ibid.*, 18.

shifts accurately that violated the FAA's scheduling policies. The audit found 279 violations of the rule requiring nine hours rest between an evening shift and a day shift, and 102 violations of the rule requiring eight hours rest between all other shifts. Many violations were more minor, as 73 percent of the total amounted to violations of less than 15 minutes in length.¹¹¹ Although a majority of them appeared to be minor, 27 percent were deemed more serious. In short, the report readily acknowledged that fatigue degrades performance and that numerous fatigue-related performance errors have occurred among air traffic controllers in recent history. Of particular note are the following two key examples of critical fatigue-related failures highlighted in the report.

- **Comair Flight 5191:** On August 27, 2006, at about 6:07 a.m., while attempting to take off from the incorrect runway at Lexington Kentucky's Blue Grass Airport, Comair Flight 5191 crashed. The investigation revealed that the airplane was cleared for takeoff by an air traffic controller who had had only two hours of sleep in the 24 hours preceding the crash.
- **Washington National Airport 2011:** On March 23, 2011, Ronald Reagan Washington National Airport was temporarily without air traffic control services. The investigation conducted to determine the reason for the service interruption revealed that the on duty controller had fallen asleep. The controller was completing a fourth consecutive midnight shift (10 p.m. to 6 a.m.).

In addition to these specific incidents, the report acknowledged that since 2011, other fatigue-related incidents had occurred at air traffic facilities in Nevada, Texas, Washington, and Florida. Since 1990, the National Transportation Safety Board (NTSB) has published an annual "most wanted list" for transportation safety improvements and every year thereafter fatigue has been on that list.¹¹² By August 2012, several significant policy changes were made to a system that already recognized fatigue as a formidable adversary. The title of the audit, *FAA's Controller Scheduling Practices Can Impact Human Fatigue, Controller Performance, and Agency Costs*, was realized in the audit's

¹¹¹ Federal Aviation Administration, *FAA's Controller Scheduling Practices Can Impact Human Fatigue, Controller Performance, and Agency Costs*, 17.

¹¹² Megan A. Nealley and Valerie J. Gawron, "The Effect of Fatigue on Air Traffic Controllers," *The International Journal of Aviation Psychology* 25, no. 1 (2015): 14–47, doi: 10.1080/10508414.2015.981488.

recommendations. It is interesting, however, that the first of the four total recommendations pertained not to fatigue but to reducing agency costs by eliminating midnight shifts at facilities that do not meet the criteria for sustained operations. The final three recommendations pertained to fatigue mitigation, requiring compliance with policies for minimum time off before returning to work and clarifying policies for recuperative breaks during the midnight shift.

Although air traffic control is a highly regulated occupation with far reaching public safety implications, controller schedules have not been standardized;¹¹³ instead, only guidelines are available that can be interpreted differently at the local level. Management and union representatives set the schedules at the local level based on workforce preference and operational needs.¹¹⁴ The “workforce preference” has resulted in a typical schedule that is popular among controllers, but less desirable in terms of fatigue mitigation. The 2012 audit report noted that no shift model is without fatigue risks.¹¹⁵ Nevertheless, it is suspicious that the audit found that a highly popular shift among controllers (i.e., the 2-2-1 counterclockwise schedule) is the least desirable from a fatigue mitigation standpoint; yet, it did not warrant mention in the recommendations section of the report. Accordingly, under the updated guidelines, operational needs and workforce preferences at each air traffic facility could dictate the actual scheduling process. For example, the counterclockwise rotating 2-2-1 schedule is popular among controllers. This coveted schedule condenses the traditional five-day workweek into four days (five shifts during four days) followed by 80 consecutive hours off. Reviews of the practice from a fatigue and safety perspective view it as a questionable practice; yet, it continues to be permitted within the broad boundaries of FAA guidelines. In short, when a union or workforce preference in a public safety environment can adversely influence fatigue mitigation scheduling, a renewed look at oversight and priorities must be considered.

¹¹³ Nealley and Gawron, “The Effect of Fatigue on Air Traffic Controllers,” 3.

¹¹⁴ Ibid.

¹¹⁵ Ibid., 9.

Also of significant concern is the difficulty that the FAA has experienced in effectively communicating significant policy changes in a concise, well-defined manner. For example, among the significant policy changes implemented in 2012, controllers were encouraged to take breaks to avoid becoming overly fatigued and to apply “fatigue mitigation techniques.” At issue is the fatigue mitigation technique of napping. The FAA fails to use the term “nap” or even “sleeping on duty,” instead depending on vague or poorly defined terms, such as “fatigue mitigation techniques” that are differentially interpreted at different air traffic control facilities. Interestingly, the audit report also failed to use specific terms in recommending corrective action on the topic of recuperative breaks. Instead, the FAA responded with precisely the same vague language used in earlier guidelines that had resulted in the need for either new recommendations or carefully outlined clarification.¹¹⁶

Another fatigue-related concern is that of off-duty work. It is difficult for any organization to mandate what an employee will or can do on a day off or on a break. Some public safety worker contracts, such as those for certain municipal police officers, limit the number of hours worked at “off-duty” employment or moonlighting. The air traffic controller’s contract is silent on off-duty activities, and instead provides a vague statement that “All operational personnel are obligated by their significant safety duties and professional responsibilities to prepare for duty with consideration for being well-rested and mentally alert.”¹¹⁷ Being “fit for duty,” which includes getting enough restorative rest, is the responsibility of all public safety workers. Recognizing that this duty is not accomplished at times, the air traffic controller contract includes the language, “It is the employees’ responsibility to recognize and report to their supervisor when they are unable to perform operational duties due to fatigue.”¹¹⁸ This policy suggests that the employer does not have responsibility to ensure controllers’ fit-for-duty, as it indicates the task is left up to the employee.

¹¹⁶ Nealley and Gawron, “The Effect of Fatigue on Air Traffic Controllers,” 20.

¹¹⁷ Federal Aviation Administration, *Memorandum of Understanding between the National Air Traffic Controllers Association and the Federal Aviation Administration* (Washington, DC: Federal Aviation Administration, 2009), 2, https://www.faa.gov/pilots/safety/media/Fatigue_MOA.pdf.

¹¹⁸ Ibid.

Regarding restorative practices, when the official rules or cultural mores shift away from prohibiting sleeping on duty, a wholesale change in policy must be explicit and not left to vague guidelines. For example, in what was an attempt to permit air traffic controller napping during breaks on the midnight shift, one sentence in FAA policy changed from “Personnel performing watch supervision duties must not condone or permit individuals to sleep during any period duties are assigned” to “Personnel performing watch supervision duties shall not condone or permit individuals to sleep while on duty.”¹¹⁹ The difference between “... any periods duties are assigned” and “... while on duty” is, at best, open for interpretation. Adding to the ambiguous language problem, the audit report indicated that most (but not all) managers participating in the study generally agreed that break time activities of controllers were not an area of concern, as long as the controllers were “fit-for-duty” upon returning from break.¹²⁰ Additional ambiguous language was contained in the policy change that allowed controllers to listen to the radio or to read “appropriate” material during otherwise monotonous periods of the night shift. What is appropriate and not appropriate is not defined in the updated regulations, which is another example of the lack of specificity in FAA guidelines. Managers have been asking for explicit guidance on existing regulatory language, particularly on the issue of napping while on the newly authorized break during the midnight shift.¹²¹ Some managers interpreted the rule to mean that napping was indeed permitted, while others perceived the rule as disallowing naps and even viewed napping as tantamount to criminal activity. This example is further evidence that a significant rule change regarding a previously taboo behavior in the overnight work culture must be clear and explicit to avoid, firstly, confusion for management and controllers, and secondly, unintended added anxiety about whether controller napping is really allowable, which itself can interrupt their restorative rest.

¹¹⁹ Federal Aviation Administration, *FAA’s Controller Scheduling Practices Can Impact Human Fatigue, Controller Performance, and Agency Costs*, 14.

¹²⁰ *Ibid.*, 13.

¹²¹ *Ibid.*, 14.

D. CONCLUSION

The aviation industry has evolved from a bravery culture to a culture of safety at a more advanced pace than that of the policing and homeland security. Aviation has earned the confidence of the traveling public through a strong record of reliability and safety, and its positive impact on society extends far beyond the trust of those who choose to fly. Recent estimates commissioned by the FAA indicate that in 2012, the U.S. economy benefited 5.4 percent as a result of civil aviation, which equates to \$1.5 trillion in products and services, and an estimated 12 million jobs.¹²² Little doubt exists that a loss of confidence in the aviation sector would be a catastrophe far beyond the immediate losses associated with any given incident. While manned flight was not originally an exercise in safety, technological advances and an understanding of human factors has allowed aviation to emerge as one of the premiere safety cultures of the world. The importance of the policies and practices in air traffic control cannot be overstated in this evolution.

Several air traffic control practices contribute strongly to fatigue mitigation and at least one that seems to hinder it. Arguably, the most important factors contributing to the industry's fatigue mitigation efforts are the FAA's and the NATCA's open acknowledgement that fatigue can have a serious impact on public safety and their cooperative efforts to mitigate those impacts. The existing contract between the NATCA and the FAA includes a section entitled "Human Factors,"¹²³ which includes clear language emphasizing that both the FAA and NATCA agree that errors resulting from human factors can be mitigated. Also, the FAA and NATCA have partnered in the collection of data associated with operational errors and in the formation of a working group to develop a fatigue management and tracking system.¹²⁴

¹²² Federal Aviation Administration, *The Economic Impact of Civil Aviation on the U.S. Economy* (Washington, DC: U.S. Department of Transportation, 2014), 15, https://www.faa.gov/air_traffic/publications/media/2014-economic-impact-report.pdf.

¹²³ Federal Aviation Administration, *Collective Bargaining Agreement between the National Air Traffic Controllers Association AFL-CIO and the Federal Aviation Administration U.S. Department of Transportation October 2009*, 143.

¹²⁴ *Ibid.*, art. 55, section no. 2 and 3.

Long before the formation of the union-management working group, both the air traffic controllers and the FAA had long recognized the crucial role the occupation plays in maintaining public safety and the unavoidability of 24-hour-per-day operations. Collision avoidance technologies have made air traffic controllers more effective in working to avoid accidents; however, human frailties will never be completely eliminated. Given the need for around-the-clock operations, the implementation of a universally perfect scheduling system is remote, which is why leaving at least some aspects of scheduling authority to local control can both help and hinder fatigue mitigation efforts. Local control allows management and union leaders to decide the best schedules for the demands of that particular workplace, but limits regulatory oversight and influence over individual centers' schedules. The result may be that personal preferences override and can be contrary to schedules that are more amenable to fatigue mitigation. Hence, this issue seems to be in need of closer examination and remediation.

Also calling for closer consideration are the FAA's rest requirements. Local schedules are impacted by the federal regulations that require nine hours rest between an evening and a day shift and eight hours rest between all other shifts. The timekeeping computer system is programmed to flag violations of these minimum time-off rules; however, non-supervisory workers can override the violation alert without supervisory approval. Further, off-duty time is a particularly troubling area because few off-duty activities can be effectively regulated and actually monitored. Controllers are required to be generally fit-for-duty at work, but no specific pre-work sleep requirement actually exists; sleep regulation compliance would be difficult to verify and all but meaningless without a way to assess the quality of the sleep. Unfortunately, perhaps the simplest way the FAA can address off-duty activities that may lead to on-duty fatigue is ignored by the agency. Simply, the FAA regulations and contracts are silent on the issue of off-duty employment or moonlighting.

The issue of shift work, especially concerns about the midnight shift, is a recurrent theme in the study of air traffic controller performance. Night-time work in general has proven to be particularly detrimental to optimal human performance, as humans are simply not intended for sustained operations and optimal performance

through the night. For air traffic controllers, the intensity of the workload may be diminished in the late night and early morning hours, which can be problematic. Incidents have been documented involving sleeping controllers, which eventually served as the catalyst for two significant changes to policy and practice. In one incident, a controller had previously been permitted to work alone through an overnight shift, making any meaningful breaks either impossible or inherently unsafe. To more readily permit breaks, the updated policy requires a minimum of two controllers through the night shift. The controversial part of this policy is that it fell short of explicitly authorizing naps or sleep during the newly permitted 2.5-hour break during that shift, which, if allowed, would likely result in controllers being more rested and alert when returning after breaks. Although less controversial, the policy that permits radios and reading material during the midnight shift lacks clear and unambiguous language, leaving individual center management with interpretation struggles.

Since the very first air traffic controller waved signals to pilots overhead, constantly improving safety margins has been the primary goal in the aviation industry. Air traffic control is responsible for a laudable safety record over the long term, yet is at least partially responsible for many accidents and near accidents. Among these mishaps and near mishaps, human factors and fatigue in particular have played more than a bit part. Just as in the night shift sleeping incidents mentioned previously, policy changes tend to be reactive rather than proactive, as corrective action is relatively quick to follow a mishap of any significance. Further, effective communication about revised and new policies from a large oversight organization like the FAA to thousands of air command centers has been problematic.

Ultimately, air traffic control as a career field is ideal for future studies on fatigue, as controllers engage in shift work and interface regularly with technology. The adverse effects of a human performance failure by those who work in air traffic control centers can reach far beyond an isolated incident. Despite advances in fatigue mitigation, aviation continues to need additional policies and clearer language about fatigue mitigation. The next chapter explores another high consequence career field; that of nuclear power controllers. Parallel to what has been seen in the air traffic control arena, adverse

incidents in the nuclear power industry have also resulted in regulatory change. Fewer opportunities for error exist, and perhaps fewer recent actual incidents or near incidents in this industry compared to aviation, but the potential for the widespread loss of life and catastrophic damage to the environment are far greater.

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IV. COMPARISON GROUP TWO—NUCLEAR POWER PLANT OPERATOR

It is just like a mule. A mule is a docile, patient beast, and he will give you power to pull a plow for decades, but he wants to kill you. He waits for years and years for that rare, opportune moment when he can turn your lights out with a simple kick to the head.

~ Jerry Pool, referring to nuclear power¹²⁵

A. BACKGROUND

Radiation has no smell, taste, or feel. Over time, the injuries and illnesses that it causes give credence to wild speculation and superstitions. In the 15th century, copper miners in Bohemia were dying of a respiratory illness at an alarming rate. The explanation was that invisible mountain dwarves were enraged by the miner's picks and shovels. The scientific explanation is that the miners were breathing radon gas from the uranium ore mixed in with the copper.

In the late 1800s, Nikola Tesla was in his laboratory when he noticed a glow on the wall and suspected that an invisible energy was being emitted from a single electrode tube. Tesla held his hand between the tube and the wall, and to his amazement, the emanations were only partly blocked; the skeletal structure of his hand was only partially blocked. He then substituted photographic plates for the wall and skeletal photos of a bird, his knee, and a shoe with his foot in it. Tesla had invented radiology. Intrigued by his discovery, he spent considerable time being x-rayed and began to observe a painful irritation of the skin, inflammation, and skin eruptions. In his final article, Tesla warned people to stay away from x-rays. Similarly, Marie Curie and her husband Pierre discovered an element that had invisible energetic influences. Unlike Tesla's invention, however, Curie's discovery did not require electricity, as the energy streamed freely from a mineral. Like Tesla's discovery, it seemed to encourage the formation of sores on the flesh that was exposed to it.

¹²⁵ James A. Mahaffey, *Atomic Accidents: A History of Nuclear Meltdowns and Disasters: From the Ozark Mountains to Fukushima* (New York: Open Road Media, 2012), 34.

A nuclear power plant is a steam engine. Water is heated beyond the boiling point and the resulting vapor is used to rotate a shaft, and ultimately, a turbine. The source of the heat in steam engines from 100 years ago was burning coal. Today, in place of coal, nuclear power plants use uranium, an element that can be highly toxic to humans.¹²⁶ At the root of accident avoidance in nuclear engineering is the problem of radiation dispersal to the public. In a nuclear power generating accident, which involves a steam explosion or the venting of steam from the reactor, highly radioactive particles created by nuclear fission are also released.¹²⁷ Throughout history, the most serious nuclear accidents were caused by reactor operator errors in which an automatic safety system was overridden by a thinking human being.¹²⁸ Today, the nuclear power industry has standards for fatigue mitigation policies and scheduling, which is the primary focus of this chapter.

The NRC is the licensing agency for operators of nuclear power plants in the United States. The NRC's mission is to "protect people and the environment from radiation hazards through regulation of the various commercial and institutional uses of nuclear material, including nuclear power plants."¹²⁹ Among the three core missions of the NRC is the establishment of standards, regulations, and requirements governing licensed activities.¹³⁰

B. CATALYST FOR CHANGE IN NUCLEAR POWER

As early as the 1970s, NRC and the nuclear power industry were beginning to take action to mitigate fitness for duty (FFD) problems at nuclear power plants. On March 28, 1979, at about 4:00 a.m. near Middletown, Pennsylvania, one of two reactors at the Three Mile Island (TMI) nuclear generating plant melted down.¹³¹ While other

¹²⁶ Mahaffey, *Atomic Accidents: A History of Nuclear Meltdowns and Disasters: From the Ozark Mountains to Fukushima*, XVII.

¹²⁷ *Ibid.*, XIX.

¹²⁸ *Ibid.*

¹²⁹ United States Nuclear Regulatory Commission, *NRC Mission Statement* (Washington, DC: United States Nuclear Regulatory Commission, 2007), 2, <http://pbadupws.nrc.gov/docs/ML0704/ML070460435.pdf>.

¹³⁰ *Ibid.*, 3.

¹³¹ "A Corporate History of Three Mile Island," accessed December 7, 2016, <http://www.tmia.com/corp.historyTMI>.

serious nuclear accidents had occurred in the United States, the NRC considers the TMI meltdown as “the most serious accident in the United States commercial nuclear plant history.”¹³² At the time of the accident, the concerned reactor, built at a cost of nearly \$700 million, had been in service for only 90 days. According to the NRC, the small amount of radiation released during the TMI meltdown did not have adverse health effects on plant workers or the surrounding population.¹³³ Still, as a result of the TMI accident, the NRC increased its regulatory oversight and made substantive changes across the spectrum of their authority, including those involving human factors.¹³⁴ The evidence is conclusive that mechanical failure was largely responsible for the meltdown on March 28, 1979. However, failures of this type are rarely attributable to one and only one cause; it is far more likely to be a confluence of factors. In this case, a leaking valve had already been identified as needing repair, and would have been repaired at the next scheduled shutdown. After the accident, that particular design would be made specifically illegal in all future nuclear plant construction.

In the 1970s and 1980s, the NRC monitored FFD programs, which were voluntary. In 1986, the NRC issued a statement that focused on the need for licensees of nuclear power plants to confront FFD issues, including legal and illegal substance abuse and any other mental or physical problems. However, the statement lacked specific guidelines for remediation and allowed facilities to address these issues voluntarily, resulting in wide disparities of quality, consistency, and comprehensiveness across all FFD programs in the nuclear energy sector. Another critical assessment was performed three years later, serving as the catalyst for the NRC to initiate a compulsory program. The details of the program were first published on June 7, 1989.¹³⁵ The new regulations

¹³² United States Nuclear Regulatory Commission, *Three Mile Island Accident* (Washington, DC: United States Nuclear Regulatory Commission, 2013), 1–7, <http://www.nrc.gov/reading-rm/doc-collect ions/fact-sheets/3mile-isle.pdf>. Note: Fatalities in experimental reactor accidents have occurred. The TMI meltdown is the most serious commercial nuclear accident.

¹³³ Ibid.

¹³⁴ Ibid.

¹³⁵ “History of The NRC’s Fitness-for-Duty Requirements,” last reviewed/updated August 12, 2013, <http://www.nrc.gov/reactors/operating/ops-experience/fitness-for-duty-programs/history.html>.

were intended to help ensure that personnel operating the nation's commercial nuclear reactors were both mentally and physically fit to perform their assigned duties.

In the 1980s, the United States Department of Health and Human Services (HHS) mandated a type of fitness-for-duty program primarily designed to prevent and detect illicit drug use. Although illicit drugs remained a significant concern in the NRC's FFD program, its mandates went several steps beyond those required by the HHS. Specifically, the NRC program allowed screening tests to be administered on-site, a seemingly minor shift in procedure with profound consequences because it helped integrate a fitness-for-duty or safety culture into the workplace. The NRC program was also more rigorous because it required testing for residual amounts of blood-alcohol content, which can serve as an indicator of acute impairment or a more chronic alcohol abuse problem. The NRC's FFD program allowed individual plant operators to establish more stringent cut-off levels than those published by the NRC guidelines.

The consideration of cut-off levels for substances is particularly important in the development of fatigue guidelines, and examining those for substances can be helpful in thinking about fatigue levels. Substance cut-off levels dictate a definitive blood level (i.e., the nanograms of a given substance per milliliter of urine) for comparison of actual test results. Those test results above the cut-off level are "positive" and indicate levels of a given substance that can lead to impaired cognitive skills, while results below are "negative" and reflect either no substance present or a level too low to be of concern. For example, for citizens licensed to drive a car or truck in most states, impairment is presumed at a blood alcohol content (BAC) of .08 percent, while for professional drivers (e.g., big rig and mass transit drivers) cut-off levels are stricter and presumptively positive, often at a BAC of .04 percent. Licensed operators of a nuclear power plant can be considered impaired at a BAC of .02 percent. In contrast, no parallel tests or cut-off levels for fatigue are available in the nuclear power or other high consequence industries even though known tests are available for measuring said fatigue level.

When the 1989 NRC rules required plant operators to address fatigue, specific limits on work hours were not mentioned or outlined. This oversight allowed for the evolution of work schedule practices involving minimum time off from work and a high

maximum number of work hours. The standardized cut-off levels for controlled substances serve as a solid model for considering the development of cut-off levels for fatigue in the nuclear power industry and other fields.

Among the volumes of regulations produced by the NRC is the FFD program, *10 CFR Part 26*, and *Subpart I Managing Fatigue*.¹³⁶ It is a complex document requiring special training and experience to understand it fully, yet willful violation of its policies can result in criminal penalties.¹³⁷ It is therefore incumbent upon individual license holders to train line employees and supervisors to implement the FFD, which includes the fatigue management plan. Recently, this plan was updated, and in accordance with a June 11, 2011 rule change,¹³⁸ the nuclear plant operator license holder retains the primary responsibility to schedule operational personnel in a manner in alignment with preventing fatigue impairment. Of particular note is that the rule change provides the license holder with additional flexibility, allowing the plant operator to conform either to the maximum average work hours or to the mandated minimum number of days off. For both options, plant operators are obligated to conform to additional fatigue mitigation rules, such as those that limit the number of hours worked to 16 within any 24-hour period, 26 in any 48-hour period, and 72 in any 7-day period,¹³⁹ as outlined in Table 1.

¹³⁶ “10 CFR Part 26—Fitness for Duty Programs,” last reviewed/updated November 8, 2016, <http://www.nrc.gov/reading-rm/doc-collections/cfr/part026/full-text.html#part026-0075>.

¹³⁷ *Ibid.*, Criminal Penalties, subsection 26.825.

¹³⁸ Nuclear Energy Institute, *Managing Personnel Fatigue at Nuclear Power Reactor Sites* (NE1 06-11) (Washington, DC: Nuclear Energy Institute, 2011), addendum.

¹³⁹ “10 CFR Part 26—Fitness for Duty Programs.”

Table 1. Minimum Day-Off Rules.¹⁴⁰

Affected Employee	8-Hour Shift	10-Hour Shift	12-Hour Shift
Maintenance	Minimum 1 Day Off Per Week	Minimum 2 Days Off Per Week	Minimum 2 Days Off Per Week
Operations	Minimum 1 Day Off Per Week	Minimum 2 Days Off Per Week	Minimum 2.5 Days Off Per Week
Security	Minimum 1 Day Off Per Week	Minimum 2 Days Off Per Week	Minimum 3 Days Off Per Week

With the added flexibility of the maximum average hour alternative, it is theoretically possible to schedule an employee to work every day except for the mandatory breaks listed in Table 1. Clearly, it would not be consistent with the spirit of the NRC fatigue mitigation plan that provides a general approach to avoiding fatigue as outlined in 10 CFR Part 26.205(c), “Licensees shall schedule the work hours of individuals who are subject to this section consistent with the objective of preventing impairment from fatigue due to the duration, frequency, or sequencing of successive shifts.”¹⁴¹ The following example highlights the issue.

John Doe is a licensed nuclear plant engineer working a nominal 8-hour day, but in an assignment not subject to work-hour rules. John has been scheduled for weekends over the last six weeks. However, during the sixth week (final week of the example) he reported to work for four hours on Saturday to “catch up on work,” and then also reported for work for four hours on Sunday. John returned to his regular schedule and duties on Monday (week seven). The following day (Tuesday), he is asked to work an 8-hour shift schedule as a senior reactor operator to fill in for the unexpected illness of a colleague. The problem is Tuesday would be John’s ninth consecutive working day, but officially his schedule does not violate any specific NRC rules.

Despite the improvement of the new rule over past fatigue mitigation regulations, it does not provide consistent protection against fatigue. It states that operators must not exceed a weekly maximum average of 54 hours worked based on a rolling period that

¹⁴⁰ Nuclear Energy Institute, *Managing Personnel Fatigue at Nuclear Power Reactor Sites* (NEI 06-11 [Revision 1]) (Washington, DC: Nuclear Energy Institute, 2008), 32, <http://www.nrc.gov/docs/ML0903/ML090360158.pdf>.

¹⁴¹ United States Nuclear Regulatory Commission, *Regulatory Guide 5.73—Fatigue Management for Nuclear Personnel* (Washington, DC: United States Nuclear Regulatory Commission, 2009), 20, <http://www.nrc.gov/docs/ML0834/ML083450028.pdf>.

cannot exceed six weeks, but the licensee operator has the discretion to establish the exact point in time during each week to mark the completion of a week of work and the start to the new week (and to not necessarily use contiguous weeks). Accordingly, an operator could, for example, decide to use the maximum allowable period (six weeks) for averaging hours, which could mean an operator could complete a seventh week because the oldest week is excluded from the averaging period.

Although the new 10 CFR Part 26.205 regulation is not perfect, it is an improvement in NRC policy. Its maximum average work (MAW) hour alternative provides plant operators flexible options for managing personnel shortages without violating rules. In instances wherein an affected employee accumulates work hours trending toward an average that will exceed the rule's limit, the remaining weeks or days can be used to reduce the average. From this perspective, the MAW rule acts as an early warning system for fatigue and for technical violations of rules. Under the minimum days-off rule, which remains a valid option for plant managers, violations could occur in as little as seven days and could not be remedied. Under that rule, an employee with a low total number of hours worked in a given week could be prohibited from providing shift coverage in a position affected by the rule depending on how much that employee worked in prior weeks. This situation would occur when an employee works a few hours on one or more scheduled days off to catch up on administrative tasks or to attend training. The "rolling" six-week period helps to prevent a manipulation of hours, which is possible in a fixed six-week period. When the hours are averaged over a fixed period, a manager could embargo hours early in the period to increase or cluster coverage dramatically at the end of the period. The recent addition of regulations of scheduling practices has resulted in evidence that the mitigation of human fatigue is a balancing act between plant operational needs and employee fatigue due to working too many hours in one day, too many consecutive workdays, or the cumulative effect of too many total hours over a much longer period.

In addition to the 54-hour average schedule policy, updated NRC regulations permit a shift manager, security watch commander, or a qualified supervisor may conduct

a fatigue assessment of an employee in certain situations. These four situations are as follows.

Cause following a critical incident—A shift manager, security watch commander, or a qualified supervisor must conduct a fatigue assessment “in response to an observed condition of impaired individual alertness creating a reasonable suspicion that an individual is not fit to safely and competently perform his or her duties, except if the condition is observed during an individual’s break period.”¹⁴² Generally, no claim of fatigue-related impairment can be made when observed during the concerned individual’s break period.

Self-declaration—As specified in the FFD program (i.e., 10 CFR Part 26.211) “A fatigue assessment must be conducted in response to an individual’s self-declaration to his or her supervisor that he or she is not fit to safely and competently perform his or her duties for any part of a working tour because of fatigue, except if, following the self-declaration, the licensee permits or requires the individual to take a rest break of at least 10 hours before the individual returns to duty.”¹⁴³

Required follow-up prior to returning to duty from a previous fatigue assessment—A follow-up fatigue assessment is required in several instances. It is most commonly required when “the previous fatigue assessment was conducted for cause or as a result of a self-declaration, and when the individual is returning to duty following a break of less than 10 hours in duration.”¹⁴⁴

Post-Event—When a critical human-error incident occurs (e.g., significant injury to a person, radiation exposure or release of radiation, or degradations in plant safety) a “post-event” drug and alcohol test shall be administered to the personnel “who committed

¹⁴² “10 CFR Part 26—Fitness for Duty Programs,” Section 26.211.

¹⁴³ Ibid.

¹⁴⁴ Ibid.

the error(s).”¹⁴⁵ This incident triggers a “post event” fatigue assessment requirement in 10 CFR Part 26.211, which states that a “fatigue assessment must be conducted in response to events requiring drug and alcohol testing as specified in 26.31(c).”¹⁴⁶

Today, the NRC’s fatigue management plan sets forth procedures designed to help ensure that worker fatigue is prevented or detected and mitigated, and that all workers are fit to perform their duties safely and maintain the health and safety of the public. Some of these policies were the direct result of information received by the NRC indicating that excessive amounts of overtime were worked (mostly by plant security personnel) in the days that followed the terrorist attacks of September 11, 2011. This information resulted in significant changes that included work-hour management systems for nuclear power licensees to manage fatigue.

C. CONCLUSION

Like the field of aviation, the nuclear energy arena has made some strides in fatigue mitigation over the last few years, but both fields demonstrate some room for further expansion of efforts to prevent human error, particularly with respect to the scheduling of employees. Recent changes and options afforded to managers in each industry provide evidence that a universally perfect scheduling system is improbable. However, the nuclear power industry more recently has stepped up its efforts to address fatigue mitigation in relation to scheduling and assessing fatigue levels. The scheduling of control room operators is now more stringently regulated than in the past, yet policies afford some manager discretion for worker preference and local conditions. Despite some flexibility, managers must comply with either minimum days off or maximum average hours worked over a designated period. While the minimum days off and the maximum average hours worked rules are improvements and provide nuanced local scheduling,

¹⁴⁵ “10 CFR 26.405 Drug and Alcohol Testing,” last reviewed/updated December 2, 2015, <http://www.nrc.gov/reading-rm/doc-collections/cfr/part026/part026-0405.html>. Note: 26.405 Drug and Alcohol Testing Serious Illness or Injury: means death, day away from work, transfer of assignments, medical treatment beyond first aide, or other significant injury or determined by a physician or licensed health care provider.

¹⁴⁶ “10 CFR 26.211 Fatigue Assessments,” last reviewed/updated December 2, 2015, <http://www.nrc.gov/reading-rm/doc-collections/cfr/part026/part026-0211.html>.

neither system excludes a required minimum number of hours off before working a shift nor the maximum number of hours that can be worked in the same day; exceptions can be made in emergencies and for planned exercises, especially for security personnel.

Regulating off-duty time is a particularly troubling area of fatigue mitigation for all disciplines, not only for the nuclear energy industry. Outside of illegal activity, few off-duty activities can be effectively required, prohibited, or monitored. Off-duty employment or “moonlighting” is not an area into which unions and management are willing to venture, as unions have historically argued that what employees do on their own time is their own business. It is improbable that controllers in either air traffic or nuclear energy would find side jobs in their career field, and would have to look for other kinds of off-duty work. Perhaps, the only high consequence occupation that affords many opportunities for off-duty employment is law enforcement or security, which can be problematic from the fatigue mitigation perspective, an issue discussed in the next chapter.

In addition to shared challenges related to scheduling of control center employees, both nuclear energy and air traffic control organizations work with businesses engaged in “for profit” enterprises that provide service to the public: Airlines in aviation and energy companies in the nuclear energy industry. However, although both types of organizations are subject to stringent federal regulations in the United States, air traffic controllers are federal (public) employees and nuclear plant control room operators can be employees of utility companies that are privately or publicly owned and operated. Both have evolved toward a safety culture, but union influence over employee scheduling is more evident in the (public) air traffic control career field than in nuclear energy control. One possible reason for the difference is linked to the safety role that air traffic controllers take on for pilots operating potentially hazardous vehicles, whereas nuclear plant controllers themselves are the “pilots” of their own potentially hazardous machines. In the field of nuclear energy, union contracts are between unions and plant owners/operators, whereas contracts for air traffic controllers are between the federal government and an association of air traffic professionals. The nuclear control contracts are largely silent on the issue of human factors and fatigue, while the federal regulations covering the operation of nuclear

power plants are voluminous, suggesting that without federal regulations, the industry would likely have inconsistent safety and fatigue mitigation standards.

Unlike the nuclear energy and aviation fields, the HSE is not largely dominated by federal regulations nor is it normally considered to be a high consequence occupation in terms of potential for widespread calamity due to a single incident. Still, the HSE is tasked with a serious public safety mission that includes the detection and prevention of acts of terrorism and other incidents that would be devastating to single or multiple communities in the United States. The HSE's mission and focus on public safety calls for a close analysis of its fatigue mitigation policies and practices, and a comparison to more leading edge industries such as nuclear power and aviation. The next chapter will explore fatigue mitigation in the context of the HSE's command center environments.

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V. HOMELAND SECURITY COMMAND CENTERS

It is totally reprehensible that the cops we expect to protect us, come to our aid, and respond to our needs when victimized should be allowed to have the worst fatigue and sleep conditions of any profession in our society.¹⁴⁷

~ William Charles Dement, MD, PhD, Pioneering Sleep Researcher

A. BACKGROUND

This chapter provides a historical review and analysis of the development of HSE command centers, followed by a discussion of the conditions that led to the rapid expansion of the fusion centers' concept and the more recent gradual growth of real-time crime centers. It then addresses major issues related to fatigue in these two types of HSE work environments, with particular focus on how the dynamics in both fusion and real-time crime centers have caused fatigue to receive dramatically less attention than it deserves.

As used in this comparative analysis, a *command center* workplace is defined as an environment in which humans interface with technology for information management and decision making.¹⁴⁸ Within this broad definition, command centers have been in existence for many decades across many fields, with arguably the most iconic being the mission control rooms created by the National Aeronauts and Space Administration (NASA), as portrayed in Figure 3. The command centers depicted in movies and television bear a remarkable resemblance to NASA's mission control rooms, as do some aspects of today's HSE centers. For the purpose of this analysis, the policies of HSE command center work environments were synthesized from two related types of HSE work environments, fusion centers and RTCCs. Like command centers in other sectors, both fusion and real-time crime centers are designed to improve situational awareness and the quality of decision making by co-locating expertise and technology and acting as information clearing houses. They differ in that fusion centers tend to be part of multi-

¹⁴⁷ Kenney and Vila, *Tired Cops: The Prevalence and Potential Consequences of Police Fatigue*, 20.

¹⁴⁸ Davis, *Making Your Command Center a Success*.

agency regional collaboratives while real-time crime centers tend to be more homogenous and tactically focused on a single city or region.



Figure 3. January 31, 1971, Mission Operations Control Room in the Mission Control Center during the Apollo 14 Manned Moon Mission.¹⁴⁹

Before analyzing how fusion centers have evolved with little regard for human factors, it is important to consider their founding documents and the urgency associated with information sharing to meet public safety needs. While some researchers have noted that functional “intelligence fusion centers” were established long before the terrorist attacks of September 11, 2001 (Rollins), proposals for real-time command centers were abundant following the terrorist attacks. In fact, six months after the terrorist attacks of September 11, 2001, the International Association of Chiefs of Police (IACP) convened a group of renowned law enforcement intelligence experts. The meeting resulted in a

¹⁴⁹ Source: “S71-16879 (31 Jan. 1971) --- Overall View of Activity in the Apollo 14 Mission Operations Control Room,” 1971, <http://www.spaceflight.nasa.gov/gallery/images/apollo/Apollo14/hires/s71-16879.jpg>.

consensus that improvements were needed in the sharing of “not only terrorism-related intelligence, but *all* criminal intelligence.”¹⁵⁰ A final report was published in August 2002 with a range of recommendations, most notably the adoption of an intelligence-led policing model, a balance of civil rights considerations, the fostering of trust between agencies, overcoming informational and analytical deficits, and addressing issues related to training and technology.¹⁵¹ An agreement was made that the significant underlying obstacles to information sharing could be solved with the development of a nationally coordinated and locally driven criminal intelligence process.¹⁵² The obstacles at that time were the de-facto “hierarchy” that made information sharing weak between the levels of the hierarchy (i.e., local, state, federal and tribal) and a related disaggregation of technologies to support analysis and intelligence sharing. Then President George W. Bush had already called for the creation of a cabinet-level DHS, which aligned with the IACP’s recommendations and gave early indications of what would become the national network of fusion centers.

The most significant document for the formation of the national network of fusion centers was the *Final Report of the National Commission on Terrorist Attacks upon the United States*. This document, which is commonly referred to as the 9/11 Commission Report, was formally released on July 22, 2004, and contains the only reference to human factors in any of the documents that gave rise to HSE fusion centers. Chapters 12 and 13 of the report (i.e., What to Do? and How to Do It?, respectively) represent the recommendations chapters of this document, and include a single reference to human factors issues, which is in its outlining of the TSA responsibilities and its role in screening air travelers. Specifically, it recommended that the TSA engage in a human factors study to understand better the primary issues in baggage screener performance and set reasonable baggage screeners.¹⁵³ It also recommended that the study’s results and

¹⁵⁰ International Association of Chiefs of Police, *Criminal Intelligence Sharing Report* (Alexandria, VA: International Association of Chiefs of Police, 2002), 4–6, <http://ric-zai-inc.com/Publications/cops-w0418-pub.pdf>.

¹⁵¹ *Ibid.*, 12–16.

¹⁵² *Ibid.*, 6.

¹⁵³ National Commission on Terrorist Attacks upon the United States, *The 9/11 Commission Report* (New York: Norton, 2004), 393.

all intelligence information be shared horizontally, which meant across new and trusted information networks. Hence, the 9/11 Commission Report called for the creation of a new network that transcended individual agencies; thereby, serving as the foundation of the national network of fusion centers.¹⁵⁴

Not long after the release of the commission's report, two additional key documents were created to facilitate the formation of HSE fusion centers, the 2003 National Criminal Intelligence Sharing Plan (NCISP)¹⁵⁵ and the 2004 Intelligence Reform and Terrorism Prevention Act (IRTPA).¹⁵⁶ The NCISP served as the blueprint for sharing criminal intelligence across the nation, while the IRTPA outlined instructions for the creation of a system-wide information-sharing environment.¹⁵⁷

In 2004, many states started operating HSE fusion centers with a variety of funding sources that afforded their speedy launch. Despite the founding documents, a standard was not created for the fusion centers to ensure interoperability and communication.¹⁵⁸ As a result of this rapid formation and lack of clear operational guidelines, the new centers were largely incapable of the intended level and type of information exchange.¹⁵⁹ To remedy this emerging problem, the Department of Justice (DOJ), formed the Law Enforcement Intelligence Fusion Center Focus Group (FCFG), which created the first guidelines for fusion centers. Those guidelines primarily focused on the foundational documents' theme of optimizing information sharing and included only a passing mention of fatigue. In short, the urgent launch and hasty development of the initial guidelines for HSE fusion centers may have facilitated the overlooking of policies and procedures for mitigating fatigue.

¹⁵⁴ National Commission on Terrorist Attacks upon the United States, *The 9/11 Commission Report*, 418.

¹⁵⁵ United States Department of Justice, *National Criminal Intelligence Sharing Plan* (Washington, DC: United States Department of Justice, 2003), https://it.ojp.gov/documents/ncisp/National_Criminal_Intelligence_Sharing_Plan.pdf.

¹⁵⁶ Congress, *Intelligence Reform and Terrorism Prevention Act of 2004* (Washington, DC: Government Printing Office, 2004).

¹⁵⁷ *Ibid.*, 4.

¹⁵⁸ U.S. Department of Justice and U.S. Department of Homeland Security, *Fusion Center Guidelines*, 1, 37, 65.

¹⁵⁹ *Ibid.*

The first annual National Fusion Center Assessments (NNFCA) was conducted in 2011, by which time, 72 operational fusion centers were in existence.¹⁶⁰ Six additional fusion centers became operational after the 2011 NNFCA and one additional fusion center became operational during the 2013 NNFCA assessment period bringing the grand total to 78. No additional fusion centers were added for the 2014 NNFCA and the number of fusion centers remains constant at 78.¹⁶¹ According to the NNFCA, “53 fusion centers operate at the state or territorial level, meaning that their areas of responsibility (AORs) encompass the entirety of their respective states or broader territories, while the remaining 25 centers operate within a narrower geographic area, usually major urban areas.”¹⁶² The NNFCA reports that “22 of the 78 fusion centers operate 24-hours per day, seven-days per week.”¹⁶³ The geographic distribution of the centers is illustrated in Figure 4.

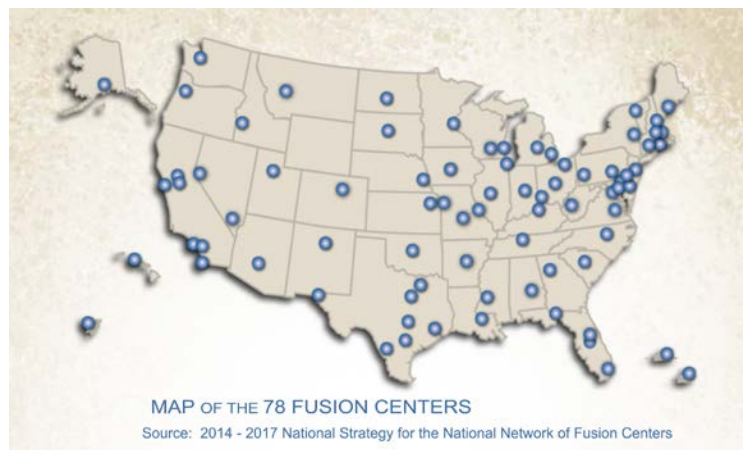


Figure 4. Map of the 78 Fusion Centers.¹⁶⁴

¹⁶⁰ Department of Homeland Security, *2011 National Network of Fusion Centers—Final Report* (Washington, DC: Department of Homeland Security, 2012), <https://www.dhs.gov/sites/default/files/publications/2011-national-network-fusion-centers-final-report.pdf>.

¹⁶¹ Department of Homeland Security, *2014 National Network of Fusion Centers—Final Report*.

¹⁶² *Ibid.*, 9.

¹⁶³ *Ibid.*

¹⁶⁴ National Fusion Center Association, *2014–2017 National Strategy for the National Network of Fusion Centers* (Washington, DC: National Fusion Center Association, 2014), 2, <https://nfcausa.org/html/National%20Strategy%20for%20the%20National%20Network%20of%20Fusion%20Centers.pdf>.

An enormous effort was put forth to prepare the foundational documents over several years in addition to conducting the four iterations of the NNFCAs to date. Still, the details of the day-to-day deployment schemes and many key safety factors are not public, and in fact, may not exist. One particular area of concern is the regard for human factors and a way to mitigate related errors. Key information is available to the public that ties closely to the human factors issues and that are worthy of examination, but they do not directly address mitigation of errors. For example, the guidelines for fusion centers recommend that wherever feasible, they operate around the clock (i.e., 24/7/365).¹⁶⁵ On record, only 22 of the 78 fusion centers are in operation 24/7/365, and at first glance, it may seem that centers that do not operate 24/7/365 fail to take on their critical mission to protect public safety around the clock.¹⁶⁶ However, the opposite could be true.

In the 2011 NNFCA, it was reported that fusion centers ranged in size from three staff members to those with over 100 personnel assigned.¹⁶⁷ In 2012, the range of the number of employees was omitted, but the median was added.¹⁶⁸ In that year, the average number of staff per center was 28, but the median was 18.¹⁶⁹ In 2013, the median was 22 and the average was 31, and in 2014, the median increased to 24 and the average to 34.¹⁷⁰ The total average and median numbers of staff grew from 2011 through 2014, with the total staffing increasing by over 500 to a total of 2,640 from 2012 to 2014, but an undetermined number of staff members are less than full-time.¹⁷¹

The current author requested scheduling and other fatigue mitigating policies from the 22 centers that operate around the clock and received information from only

¹⁶⁵ U.S. Department of Justice and U.S. Department of Homeland Security, *Fusion Center Guidelines*, 6.

¹⁶⁶ Department of Homeland Security, *2014 National Network of Fusion Centers—Final Report*, 9.

¹⁶⁷ Department of Homeland Security, *2011 National Network of Fusion Centers—Final Report*.

¹⁶⁸ Department of Homeland Security, *2012 National Network of Fusion Centers—Final Report* (Washington, DC: Department of Homeland Security, 2013), 4, <https://www.dhs.gov/sites/default/files/publications/2012%20National%20Network%20of%20Fusion%20Centers%20Final%20Report.pdf>.

¹⁶⁹ *Ibid.*, 4.

¹⁷⁰ Department of Homeland Security, *2013 National Network of Fusion Centers—Final Report* (Washington, DC: Department of Homeland Security, 2014), <https://www.dhs.gov/sites/default/files/publications/2013%20National%20Network%20of%20Fusion%20Centers%20Final%20Report.pdf>.

¹⁷¹ Department of Homeland Security, *2014 National Network of Fusion Centers—Final Report*, 11.

three: the Indiana Intelligence Fusion Center (IIFC), the Delaware Valley Intelligence Center (DVIC), and the Chicago Crime Prevention and Information Center (CPIC). The other 19 centers were not responsive to requests. Hence, the remainder of this chapter analyzes the work schedules and fatigue-mitigation efforts of those three centers, one a fusion center for an urban environment, and the other two having oversight of broader territories.

B. INDIANA INTELLIGENCE FUSION CENTER

The IIFC mission is to “collect, evaluate, analyze, and disseminate information and intelligence data regarding criminal and terrorist activity in the state of Indiana while following fair information practices to ensure the rights and privacy of citizens.”¹⁷² IIFC officers are generally deployed 8 to 8.5 hours per day, five days per week on fixed shifts to cover a 24-hour deployment.¹⁷³ The IIFC policies and procedures are silent on the specific issue of fatigue. Furthermore, the IIFC reported it uses only general administrative processes to measure work performance, such as a supervisory review of work for legal sufficiency, accuracy, and completeness. In response to a public request for information, the official IIFC response to the current author was that it had no specific fatigue management plan although the center has a system for thorough peer and supervisory review of IIFC work products. Although the system may be helpful in determining whether individuals may have been fatigued *after* their shift, it does not serve as a tool for proactively identifying the level of fatigue. Instead, it serves as an administrative process for checking work and for identifying and correcting errors, and its results can lead to detecting areas in which staff may need additional training. While it is possible that when excessive errors occur, the supervisor will conduct some form of fatigue assessment, no policy or formal process exists for requiring it or outlining how to conduct that type of evaluation.

¹⁷² “Mission Statement,” accessed December 7, 2016, <http://www.in.gov/iifc/2336.htm>.

¹⁷³ Some officers and some civilians are permitted to work alternative 10 hour watches. Most others work 8 to 8.5 hours per day.

Similar to over 60 percent all fusion centers, the IIFC is by design a multi-agency organization with staff from various employers and under differing unions or labor contracts, indicating that the employee requirements can vary and the issue is complex. The materials received by the current author indicate the labor contracts for the IIFC do not address fatigue nor do they have specific work schedule requirements. Interestingly, after considerable research of publically available information, a public record of human error or any errors attributable to the IIFC was not found.

C. DELAWARE VALLEY INTELLIGENCE CENTER

The DVIC advertised itself as a “24/7 all-hazard, all-crime, information and intelligence collection, analysis, and dissemination facility.”¹⁷⁴ The DVIC’s mission is to “support and enhance public safety” operations in narrow portions of a four-state (Delaware, New Jersey, Pennsylvania, and Maryland) Delaware Valley region, and therefore, not the primary fusion center for any of the four states (Delaware, New Jersey, Pennsylvania, or Maryland). Personnel assigned to the DVIC alternate between a day shift (i.e., 8:00 a.m. to 3:00 p.m.) and a swing shift (i.e., 3:00 p.m. to 11:00 p.m.). Civilian analyst personnel are assigned to the day shift and are generally not required to rotate shifts.¹⁷⁵ Like many other large and medium-sized police departments in the United States, the Philadelphia Police Department (PPD) has established a RTCC, which like at least eight other fusion centers, is co-located on the same physical plant.¹⁷⁶ During the nighttime or graveyard shift, when the DVIC has no personnel deployed, the PPD RTCC is responsible for fielding calls for the DVIC.

The RTCC in Philadelphia is generally staffed with only two or three people covering the overnight shift on most nights. The sworn personnel assigned to the DVIC are required to alternate between the day shift and the swing shift every two weeks. The civilian personnel (e.g., analysts) are assigned to a fixed day shift. The personnel assigned to the PPD RTCC are generally assigned to one of three eight-hour shifts that

¹⁷⁴ “About DVIC,” accessed December 7, 2016, <http://www.stayaalertnow.com/about-dvic>.

¹⁷⁵ The Delaware Valley Intelligence Center responded to a request for information.

¹⁷⁶ Department of Homeland Security, *2014 National Network of Fusion Centers—Final Report*, 10.

conform to the city's PPD schedule. Day watch employees work from 6:45 a.m. to 3:00 p.m. and the afternoon or evening watch works from 2:45 p.m. to 11:00 p.m., and the morning watch, which the PPD refers to as "last out," works from 10:45 p.m. to 7:00 a.m. The personnel assigned to the day and the swing shift alternate between the two shifts every two weeks in accordance with an annually produced schedule. The graveyard shift or "last-out" shift does not rotate, and hence, maintains the same shift over time, which may be beneficial from a fatigue mitigation schedule. However, based on information made available to the current author, the DVIC does not have a specific fatigue mitigation plan, and no public record of human error or any notable failures attributable to the DVIC was found. In addition, it is unclear how the night shift, which represents a riskier time for fatigue problems, is supervised.

D. CHICAGO CRIME PREVENTION AND INFORMATION CENTER

The CPIC in Chicago, Illinois is a recognized fusion center that operates on a 24/7/365 basis. Officers assigned to the CPIC generally work four days in a row in nine-hour shifts followed by two days off. Officers pick their preferred watches annually based on seniority. In reviewing the agency's documents, it appears that similar to the DVIC, the CPIC has no specific fatigue management plan, which may be related to its centers being staffed by multiple agencies. In fact, many of its personnel are from agencies not bound by the Chicago Police Officer's (CPO) CBA, based on information provided by the CPIC. While the CPIC and the CPO CBA are silent on fatigue mitigation, the CPIC does require staff participation in quarterly safety meetings, and both parties (i.e., lodge and employer) formally agree to cooperate to the fullest extent to promote safety.¹⁷⁷

E. CATALYST TO CHANGE—A CASE STUDY OF THE LOS ANGELES POLICE DEPARTMENT

The LAPD's RTCC is the only command center work environment in this policy analysis study that is regularly audited for compliance with a vigilance task deadline. A vigilance task deadline for the purposes of this thesis is a response-time standard

¹⁷⁷ Fraternal Order of Police Chicago Lodge 7, *Agreement between the Fraternal Order of Police Chicago Lodge No. 7 and the City of Chicago* (Chicago: Fraternal Order of Police Chicago Lodge 7, 2007), 12, http://www.chicagofop.org/contract/contract_07-12.pdf.

established in the interest of public safety. For example, the National Emergency Number Association (NENA) has established a standard for the answering of emergency calls at public safety answering points (i.e., 9-1-1 call centers). The current NENA standard is that 90 percent of 9-1-1 calls should be answered within ten (10) seconds during the busy single hour of the day and 95 percent of all 9-1-1 calls should be answered within 20 seconds.¹⁷⁸ The LAPD's RTCC is required to make certain critical notifications within 20 minutes.¹⁷⁹ This particular vigilance task deadline evolved over several years and was fueled by key events, each of which was laden with human factor issues.

The first incident was the use of excessive force against Rodney King, then a 25 year-old parolee. The Rodney King beating, as it has become commonly known, occurred at about 12:40 a.m., on Sunday morning March 3, 1991, and was captured by an amateur on a consumer grade camcorder. The incident served as the catalyst for several inquiries into the LAPD, most notably, the 1991 Report of the Independent Commission on the Los Angeles Police Department (Independent Commission). The Independent Commission concluded that the LAPD's system of discipline needed a major overhaul, including the creation of a permanent, independent, and full-time oversight authority. The Office of the Inspector General would carry out its significant authority over both sworn and civilian employees of the LAPD and would have the power and duty to initiate and conduct investigations and audits, and to oversee the handling of all complaints of misconduct handled within the police department.

By 2001, numerous other reports of excessive force, corruption, and leadership scandals had been reported. The DOJ notified and filed a lawsuit against the City of Los Angeles based on an alleged pattern and practice of civil rights abuses allegedly perpetrated by the LAPD. A settlement with the federal government imposed several requirements on the LAPD, one of which would be timely notifications following the use

¹⁷⁸ National Emergency Number Association (NENA), *NENA Call Answering Standard/Model Recommendation* (Alexandria, VA: National Emergency Number Association (NENA) Standard Operating Procedures Committee, 2006), 8, https://c.ymcdn.com/sites/www.nena.org/resource/resmgr/Standards/NENA_56-005.1_Call_Answering.pdf.

¹⁷⁹ Audit Division, *Categorical Use of Force Process Audit* (Los Angeles: Los Angeles Police Department, 2014), http://www.lapdpolicecom.lacity.org/072214/BPC_14-0285.pdf. Note: This document cites LAPD Department Manual Section 4/204.80.

of deadly force by a Los Angeles police officer. One way the city could meet the timeliness requirement was through the establishment of a RTCC, which the LAPD eventually activated in 2005. Compliance audits on these timed notifications have created the only known vigilance test in the sample of RTCCs.

F. THE DEVELOPMENT OF REAL-TIME CRIME CENTERS

Just prior to the launch of LAPD's first RTCC, in the same year, the NYPD activated the first RCTTs in the United States. When the current author contacted the NYPD, its leadership graciously responded to the request for information about its RTCC. As in many jurisdictions, the identification and apprehension of criminals had been hindered not by a lack of information, but by the lack of a system to access the information quickly. The combination of state-of-the-art computer technology, experienced personnel, and around-the-clock deployment, was the beginning of the RTCCs. The centers provide rapid and highly sophisticated computer search capabilities to investigators in the field to assist in the quick identification and apprehension of violent criminals before additional crimes can occur. The success of this concept stems from the innovative use of data mining technology to overcome what has been a persistent organizational challenge to law enforcement agencies, which is how to make quick and effective use of the large volumes of computerized data already available.¹⁸⁰

Officers assigned to the RTCC work five consecutive days followed by two days off, and officers working beyond their tour of duty or on their days off are paid overtime. The NYPD RTCC is a 24/7/365 command center-type operation with three shifts: 6:00 a.m. to 2:33 p.m., 2:00 p.m. to 10:33 p.m., and 10:33 p.m. to 6:33 a.m. Employees are assigned to one of three shifts and are not required to change shifts on any scheduled rotation, but can trade shifts with other officers if operations will not be impacted. Vigilance tests are conducted by a variety of units within the NYPD, including but not limited to the Internal Affairs Bureau and the Offices of Chief of Department and Chief

¹⁸⁰ NYPD Real Time Crime Center, *Executive Summary* (New York: NYPD Real Time Crime Center, 2007), 1. Provided in response to a request for information.

of Patrol. The tests vary in nature and can be conducted at any time.¹⁸¹ A search of public records did not find evidence of a failed vigilance test or any other human failure for the NYPD RTCC in the history of the RTCC.

In 2005, the LAPD activated its RTCCs and dubbed them collectively as the Real-Time Analysis (RTA) and Critical Response Division. Each of the real-time crime centers has unique features, but they are similar in that they are largely homogeneous. The LAPD's RTA centers are staffed almost entirely by sworn and civilian employees of the LAPD, and accordingly, all are employees of the City of Los Angeles and not of multiple agencies.

In February 2008, through the restructuring of other department functions, the HPD created a 24-hour per day, seven-days per week real-time crime center.¹⁸² Like the NYPD concept, the HPD approach was to leverage technology to support field investigators in "real time."¹⁸³ Similarly, the Memphis Police Department (MPD) responded to a request for information about its RTCC, which launched operations in April 2008. The MPD's RTCC uses state of the art technologies to monitor, evaluate, and predict criminal activity on a 24/7/365 basis,¹⁸⁴ and is responsible for public access to crime-related data. The MPD RTCC also facilitates interagency cooperation between city, county, state, and federal law enforcement through a data and resource-sharing initiative.¹⁸⁵

In these centers, officers are assigned to one of three shifts: The A Shift, from 11:00 p.m. to 7:00 a.m., the B Shift from 7:00 a.m. to 3:00 p.m., and the C Shift from 3:00 p.m. to 11:00 p.m. The entire MPD is subject to a rotating schedule of continuous days off: Monday and Tuesday, Wednesday and Thursday, and Saturday and Sunday. Friday is generally a day when all personnel work, and every 28 days each section

¹⁸¹ No public record of human error was requested or received. A search for a public record of human error or any failure attributed to the NYPD RTCC met with negative results.

¹⁸² Houston Police Department, *Annual Report* (Houston: Houston Police Department, 2010), 5.

¹⁸³ *Ibid.*

¹⁸⁴ "Real Time Crime Center," accessed December 7, 2016, <http://www.memphispolice.org/rtcc.asp>.

¹⁸⁵ *Ibid.*

progresses to the next set of days off. Officers can experience a five-day stretch of off-work when they opt to use a “benefit day” off on a Friday between the progression of Wednesday and Thursday off and Saturday and Sunday off. For a four-day stretch of time off without using a benefit day, the officers are permitted to trade a Wednesday off for a Friday off. While this progression allows for an occasional long stretch of time away from work, it also requires officers to work seven-day stretches during the progression from Saturday and Sunday off to Monday and Tuesday off. The same is true in the progression between Monday and Tuesday off and Wednesday and Thursday off. The MPD memorandum of agreement (MOA), like most collective bargaining contracts includes a standard occupational health and safety provision, but despite some of the challenges likely related to working seven days straight, the MPD MOA is silent on fatigue.¹⁸⁶

G. CONCLUSION

Command centers in the HSE, whether fusion centers, real-time crime centers, or hybrid centers operating as both fusion or real-time crime centers, have in common that they are increasingly rich in technology and humans play a significant decision-making role in furtherance of public safety. While some progress has been made in developing fatigue mitigation policies, based on available federal documents and documents supplied by the fusion centers responsive to data requests, gaps continue to exist in formalized fatigue mitigation management and assessment across the nation. The LAPD’s RTCC has made some progress in regards to work schedules that largely, but not exclusively, mitigate fatigue, but they lack comprehensive, regulated, and monitored fatigue mitigation policies.

This finding in part may be related to the role that federal funding plays. At present, fusion centers, but not real-time centers, rely heavily on federal funding, and as such, are subject to federal inquiries and audits. In a methodology remarkably similar to the constant comparative method, federal inquiries of fusion centers have involved close

¹⁸⁶ Memphis Police Association and the City of Memphis, *Agreement between the Memphis Police Association and the City of Memphis, Tennessee* (Memphis, TN: Memphis Police Association and the City of Memphis, 2011), http://www.memphistn.gov/portals/0/pdf_forms/mou/mpa.pdf.

monitoring of their maturation and ongoing discussions of successes and failures through a largely unstructured sharing of information with stakeholders and through the examination of the documents that they produce. These processes may have been beneficial to the growth of fatigue mitigation in fusions centers, but only to a very limited degree, as gaps in both ongoing fatigue assessment and management exist. The issue is exasperated among RTCC, particularly when they exist independent of a fusion center. In those instances, they lack universal guidelines, best practices, and any form of accreditation, in part because they tend to be developed and sustained without ongoing federal funding. Hence, despite the critical role that RTCC play in public safety and the prevention of terrorism, they have remarkably low regard for human factors and fatigue.

In the following chapter, the present researcher comparatively analyzes the command centers of HSE, aviation, and the nuclear industry to develop a grounded theory for the current status of fatigue mitigation and human factor concerns in the HSE. To accomplish the detailed comparison, similarities and differences in each of the three organizations were examined and involved consideration of relevant public mandates and the corresponding speed at which they evolved, the safety and bravery cultures in the workforce, collective bargaining agreements, and governmental oversight. The results facilitated the development of a grounded theory on the state of human factors and fatigue mitigation in the HSE, which was useful in making recommendations for fatigue mitigation guidelines in command centers where they may be presently inadequate, as outlined in Chapter VII.

VI. DISCUSSION AND ANALYSIS

A. INTRODUCTION

In this chapter, the author compares the command center work environments of the air traffic control, nuclear power generation, and homeland security career fields along three different dimensions. The first dimension is the historical evolution of the three fields' command center work environments to provide a generalized analysis of the similarities and differences regarding the major historical influences on their respective workplace environments (e.g., technological milestones, accidents, and public confidence). The second dimension, an outflow of the first, is the state of the respective career cultures, which are analyzed through comparisons of the maturity of the respective fields, career paths, and the nature of their adversaries from which two competing cultures emerge, safety and bravery. The third and final dimension examines the respective laws, regulations, work rules, and any accepted practices that may serve to mitigate or aggravate human fatigue and errors, with a special focus on scheduling policies, collective bargaining, the investigation of errors, FFD programs, including on and off-duty employment requirements related to moonlighting and residency requirements.

This constant comparative analysis addresses the research question of how current practices in the fledgling command centers of the HSE conform to the command centers of two high-consequence pioneering fields that have been in existence for decades. The answer to the research question also yields a grounded theory to explain the state of fatigue mitigation practices within the command center work environments of the HSE. This output serves as a basis for several recommendations aimed to improve human performance in the HSE and potentially other command center work environments, both public and private.

B. EVOLUTION OF THE THREE FIELDS' COMMAND CENTERS

Air traffic control and nuclear power generation evolved along similar trajectories. The inventions and discoveries that led to manned flight and nuclear energy

production created a risk to public safety, which had not in any substantial way existed previously. In terms of policing, the risk to public safety was not the result of a specific invention or discovery. Instead, policing emerged from the general need to protect the public from problems arising out of the human condition, such as from evildoers who have existed since the beginning of documented history. This section analyzes the evolution of the three fields' paths and describes how their evolutionary trails led, or failed to lead, to considerations of human error.

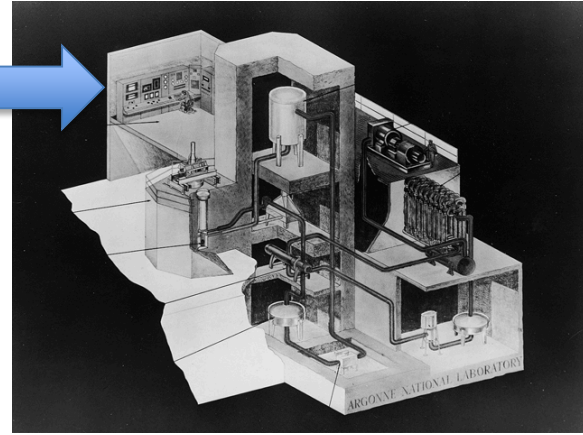
The process of discovering, understanding, and applying nuclear energy resulted in illness and injury to the scientists long before the actual creation of the nuclear power generation industry. Although nuclear power plants do not contain adequate quantities of nuclear material to detonate like an atomic bomb,¹⁸⁷ the public sentiment related to anything associated with nuclear material has been and will be forever tainted by the use of nuclear fission for military purposes.¹⁸⁸ The opposite of an atomic detonation is a “controlled” atomic reaction, which is the goal of the nuclear power industry. Early on, great emphasis was placed on the ability to control the atomic reaction, and beginning with the very first nuclear reactor (see Figure 5), every nuclear generation plant in the world has had a control room. Nuclear power control room personnel were necessary to detect problems and make adjustments, which would ensure a reliable source of electricity and the containment of radiation. In the same way that pilots drive the airplane, nuclear power plant control room personnel drive the plant. Nuclear power plants produce electricity and airplanes produce flight; the effectiveness of the human-in-the-loop is measured by the absence of accidents. No analogous product or goal (e.g., to make safe electricity or flight) exists for HSE control rooms, except that its control rooms mitigate all hazards and promote universal safety.

¹⁸⁷ Jenny Marder, “Nuclear Reactors And Nuclear Bombs: What Defines The Differences?,” Blog, *PBS Newshour*, 2011, <http://www.pbs.org/newshour/rundown/what-is-the-difference-between-the-nuclear-material-in-a-bomb-versus-a-reactor/>. Note: Marder quoted Arjun Makhijani, President of the Institute for Energy and Environmental Research.

¹⁸⁸ Harold Feiveson, *On the Global Nuclear Future* (Cambridge, MA: MIT Press for the American Academy of Arts and Sciences, 2009), 65.



Control Room, Idaho National Laboratory¹⁸⁹



Experimental Breeder Reactor (EBR) No. 1¹⁹⁰

Figure 5. First Nuclear Reactor and Control Room.

Experts generally agree that three generations of nuclear power plant control room designs exist, and the earliest to the latest designs have focused on increased profitability through the prevention of costly accidents (including those caused by human error), enhanced reliability, and overall safety. As of August 2015, the NRC licensed and monitored 99 licensed commercial nuclear power reactors operating at 61 sites in 30 states.¹⁹¹ The newest reactor began producing electricity in 1996 and the two oldest reactors each began their service lives on December 1, 1969.

In 1975, about six years after the launch of the earliest reactors still in existence today and long before the most serious fatigue-related nuclear disasters at Chernobyl and TMI, the International Atomic Energy Agency Working Group on Nuclear Power Plant Control and Instrumentation sought to improve information management in control rooms.¹⁹² Hence, prior to any major incident, the agency was focused on improving

¹⁸⁹ Source: “Nuclear Pioneers: EBR-1,” 2003, <http://www4vip.inl.gov/eb1/>. This image was captured from the EBR-1 tour video at time stamp 1:36 to 1:40.

¹⁹⁰ Source: Susan Stacy, *Proving the Principle* (Idaho Falls, ID: United States Department of Energy, 2000), 47, http://www4vip.inl.gov/publications/d/proving-the-principle/chapter_06.pdf.

¹⁹¹ United States Nuclear Regulatory Commission, *Nuclear Reactor* (Washington, DC: Nuclear Regulatory Commission, 2014), <http://www.nrc.gov/docs/ML1525/ML15254A456.pdf>.

¹⁹² International Atomic Energy Agency, *Control Room Systems Design for Nuclear Power Plants* (Vienna, Austria: International Atomic Energy Agency, 1995), http://www.iaea.org/inis/collection/NCLCollectionStore/_Public/27/002/27002051.pdf.

safety. Four years later, the 1979 TMI nuclear accident caused the NRC to develop an action plan that required plant operators to perform sweeping reviews of their control rooms to correct design deficiencies.¹⁹³ Control rooms in service in 1979 were virtually all first generation control rooms in need of modernization. They had fixed components, such as single purpose switches, pressure gauges, indicator lights, and annunciator panels, and varied widely from one early design to another. The placement of the equipment was, at best, based on a common sense assessment of what operators would likely need in common situations. First generation control room operators in a novel situation might have to scurry from position to position to gather and collate information, causing them to be overwhelmed trying to distinguish between significant and insignificant information.¹⁹⁴ Technological advancements allowed second generation control rooms of the mid-1990s to have computers and screens, resulting in a more compact and organized display of the relevant information needed for the situation at hand. They significantly reduced the cognitive workload of the operator for the tasks of trend detection and deciding which action is the most important to take first. Also, the technical enhancements leveraged the ergonomic and human factor research of the emerging computer industry. For example, in a second generation control room, an alarm would not only sound, but would be attenuated, analyzed, and the problem diagnosed, and the desired response would then be identified.

Third generation systems were marked by even more advanced computers, electronic display, and technology and made use of the most current human factors research. In other words, they further removed reliance on the operators' cognitive skills and judgment both to detect problems and to resolve them while allowing for levels of automation and networking which, for example, increased safety by permitting plant shutdown without direct access to the control room and by allowing experts outside the plant to deal with issues collaboratively.¹⁹⁵

¹⁹³ Neville A. Stanton, *Human Factors in Nuclear Safety* (Boca Raton, FL: CRC Press, 1996).

¹⁹⁴ International Atomic Energy Agency, *Control Room Systems Design for Nuclear Power Plants*.

¹⁹⁵ *Ibid.*, 18–19.

Air traffic control work environments also sought to capitalize on both the technological advancements available at each point in time and the state of behavioral sciences research, which included increasing knowledge of the strengths and weaknesses of the command center operator; however, the nuclear energy industry does present some differences. The earliest difference was in the very nature of what can be seen as the very first air traffic control room, the cockpit. Simply put, the earliest air traffic control was the responsibility of the individual pilot while in the cockpit, a concept known as “see and be seen.” It could be argued that the arrangement in early aviation of one cockpit per airplane was similar to the nuclear energy’s one control room per plant. The operator in both fields had one entity to manage. However, in sharp contrast to both the HSE and nuclear power command center’s nascent work environments, in early aviation, there were more physical plants and vastly more territory across which the potential for an accident existed, as pilots and their aircraft covered a large geographic area during each flight. Following a set of key human factors-related accidents, there was a move to regulate the industry and to take some of the responsibilities for collision avoidance off the shoulders of the pilot. The result was that the aviation industry regionalized control early in the aviation process, which was very different from the nuclear power industry, which never regionalized control in any significant way.

As with the nuclear energy industry, technological advances made aviation possible, but it was both technology and catastrophe that served as the catalyst for change in the manner aircraft became regulated and controlled. As mentioned earlier, the nuclear power industry strived to regulate and update its control rooms prior to the experience of major catastrophes or incidents, but for aviation, repeated midair collisions led to considerably more focus on enhancing control and regulations. With the shift to command centers in aviation, the pilot was allowed to focus more attention on flying the plane, and less on typical command center tasks, such as tracking other airplanes. However, although airline companies had dispatchers serve as their first controllers, collision avoidance was still the primary responsibility of the crew in the cockpit. In the mid-1950s, the airline company dispatchers did not have the ability to help pilots avoid in-air collisions. Instead, they controlled the flow of traffic coming in and leaving the

airport and sounded the alarm that their aircraft were overdue to check in. When collisions took place, the dispatcher would find out after they occurred.

The first control rooms in the HSE were arguably dispatch centers not so different from the mid-1900s dispatch model of the aviation industry. In the same way that early HSE dispatchers were often taken from the sworn ranks, early air traffic controllers were required to be pilots. Certain types of early technology also played a role in these two fields' early command centers. For example, wired telegraphy made it possible for dispatchers to receive calls from anyone with access to connected equipment. In regards to policing, foot beats and field patrols would call in at regular intervals to receive directions and provide or gain information. For aviation, wired telegraphy allowed dispatchers to report arrivals, departures, and perhaps, most importantly for safety considerations, when aircraft were overdue.

Eventually, lights on top of buildings or towers and horns or sirens would serve as an indicator or alarm to call the attention of first responders beyond the range of the nearest telegraphy station. One-way, and later, two-way radio communication extended the range and the immediacy of the communications. This expansion was especially important to the HSE and aviation, which have operations that are inherently mobile, and less important for the nuclear power industry, which had command centers that monitored fixed locations. Public safety did not hesitate to embrace the new radio technology, and in 1923, the Detroit Police Department was the first agency to use radio communication and did so regularly and reliably by 1928.¹⁹⁶ Between 1931 and 1937, the number of agencies using radios grew from four to over 2,000.

One reason the streamlined dispatch and information sharing was more crucial for HSE and aviation is related to the two fields' command centers regions of oversight in relation to the centers' locations. For both the HSE and aviation, in general, the risk for accidents and catastrophic events are largely offsite or a substantial distance from the command center. In nuclear power, relatively few physical plants are in existence, and the risks associated with them are within the plants and immediate areas. Embracing

¹⁹⁶ Joseph A. Poli, "The Development and Present Trend of Police Radio Communications," *Journal of Criminal Law and Criminology* (1931–1951) 33, no. 2 (1942): 193, doi: 10.2307/1136443.

technological advancements in telegraphy allowed air traffic control and the HSE to not only do their jobs more effectively, but also to consolidate large numbers of staff in more regional centers to oversee vast geographic areas, likely creating new ways that human error might play a role in operations.

In the third or most recent evolution of control centers, all three fields have clearly benefitted from recent technological advancements. However, unlike the HSE's growing command centers, those in aviation and in nuclear energy are accompanied by extensive regulation and utilize information from human factors research. In the HSE, there is little regulation and little if any consideration for human factors. While automation has added efficiencies and effectiveness to all three fields, at least a perceived need for humans in each of the three comparison fields remain, and humans continue to play a major role in these operations. This consideration is particularly important given that air traffic can be slowed or brought to a standstill in an emergency and a nuclear power plant can similarly be shut down. However, for HSE command centers, the immediate risk to public safety cannot be eliminated; the billions of people in the world cannot be "controlled" at any one point in time. Despite the fact that HSE command centers and the risks to public safety they oversee cannot be stopped or shut down, the HSE is the only command center environment to date without a catastrophe directly linked to a known human factor or fatigue failure, which is quite different from the other two comparison fields. In both aviation and nuclear energy, human factors and fatigue in particular have been correlated to multiple failures. In addition, for those two fields, the ongoing catalyst for command center improvements has been catastrophes. The author contends that the fact that the United States has not experienced public safety catastrophes associated with human fatigue or error by a single command center employee may explain in part why to date, unlike the other two fields, the evolution of HSE command centers has not involved strong regulation, certification, or accreditation processes of any type.

In conclusion, along the evolutionary lines for all command centers, evidence states in the comparative analysis that an articulable risk for a catastrophic event contributed to the eventual creation of command centers in each field. However, evidence

also shows that it was not the threat of a catastrophe alone, but the simultaneous existence of adverse public sentiment and the readiness of adequate technological advancement. Although the three fields differ in the timing of the development of their centers, each has evidence of these three elements as driving forces at some point along their evolutionary paths: threats of catastrophe, adverse public sentiment, and adequate technological readiness. The HSE was the last of the three fields to develop command centers since a catastrophic event on U.S. soil only occurred as recently as 2001. Nonetheless, in vary degrees, each of these required catalysts for change are linked to human errors of commission or omission, but perhaps overall, less so for the HSE.

C. THE ROLE OF THE CULTURE OF BRAVERY

It could be argued that all three career fields were influenced by a culture of bravery, although in the HSE, it is much more pronounced today. The bravery culture was strong historically, or in the early days of the other two industries, but for a number of reasons, that culture weakened, which has helped them create a safety culture, and ultimately, led them to a focus on human factors and fatigue.

The precursor to the aviation industry, which was the desire to fly, was spawned by the sense of bravery, adventure, and dare-devilism. Similarly, nuclear scientists exposed themselves to risks, first to create bombs to win World War II, then later for energy usage, despite fears of the unknown and invisible. For example, the term “the China Syndrome” was initially used to describe what some thought would happen in a nuclear meltdown, the core would continue to travel through the earth toward China. Hence, like aviation, in its earliest days, the nuclear power industry embraced a culture of bravery against a difficult-to-detect, invisible, and deadly chemical risk. The question remains, however, of what led to the parallel shifts in those two industries regarding the bravery culture, but failed to impact the HSE?

For both nuclear power and aviation, the desire to achieve and actually achieving reliable and safe operations led to commercial applications and added to an already existing interest for military applications. Arguably, bravery and risk-taking that allowed these fields to develop early on became inconsistent with the public’s desire for reliability

and for experts of these respective fields to achieve mastery that necessitated the move toward a culture of safety. In other words, these two fields' ability to generate widespread public acceptance was based on a demonstrated record of reliability and safety, as well as a move away from being viewed as industries based on bravery and risk. In the field of crime and terrorism, it was not possible to achieve mastery, as the adversary in crime and terrorism is and has always been thinking, breathing, and numerous (potentially billions of people). In fact, members of the HSE, and especially first responders, are frequently lauded as heroes for running toward danger when others run away.

It could be argued that the nuclear plant operators potentially remain in harm's way to save others at their own peril should a nuclear leak or accident occur. However, the difference is that for the HSE, the adversary is an intellectual being or set of beings who can adapt to strategies employed by the responder. This fact alone makes guaranteed safety an unachievable ideal and can be a reason that the HSE has not and may never fully place safety as its top priority; instead, bravery must hold that position. Given that street criminals and terrorists are the opponents in homeland security, unlike radiation leaks and mid-air collisions, safety measures developed for the HSE have historically resembled a chess match involving the ability to act and react; a set of back and forth reactions or "moves." As mentioned in the previous section, in nuclear power, the nuclear energy plant can shut down and planes can be grounded, but for the HSE, operations can never cease since criminals never stop and can threaten the United States anywhere in its large geographic area. Hence, HSE was and has been less inclined to move away from a culture of bravery to one of safety compared to the other two fields.

This paper's author contends that the over-focus on bravery has contributed to the HSE's lack of focus on human error and fatigue. In short, a refusal to go into harm's way is not an option in military and police work, and those who work in the HSE must see and go after the cause of the risk. That risk is most often a human adversary; in the other two fields, the adversary is not human and often less persistent compared to terrorists, for example.

It might be expected that the culture of bravery would have persisted in the nuclear power industry as it has for the HSE, but for a different reason. In the comparison

of the three command center environments, the potential physical danger experienced by the three command center operators is far greater in the field of nuclear power generation. Despite the suggestion that operators in this industry must inherently be brave given that risk, the industry has increasingly moved away from the culture of bravery and focused more on safety and avoiding human error, which may be related to the industry evolving from hard science, for which outcomes for given actions are highly predictable. Scientific analysis of the nuclear accidents at Three Mile Island and Chernobyl resulted in the coining of the term “safety culture.”¹⁹⁷ From that point on, the industry has focused on safety over bravery. In contrast, the evolution of the safety culture for aviation likely arose out of the realization that accident rates were low because of the focus on pilot and control operator skill mastery, and that when accidents occurred, they were usually the result of human error despite the high level of mastery.

A related factor in the safety and bravery comparison is the nexus between the accident itself and the attribution of fault. In both the aviation and nuclear power fields, after an accident or catastrophe of any level, a systematic investigation is done that accurately and sometimes rapidly attributes fault to specific individual operators or staff. Hence, in the nuclear power and aviation industries, carelessness, risk, and bravery are not valued and contradict safety values. In contrast, in the HSE, the catastrophic incident is rarely an “accident,” and instead, likely the result of an intentional act that necessitates a significant investigation to apprehend an offender who is most often not in any way affiliated with the HSE command center. Hence, determining and investigating internal fault is not inherent to the HSE or policing field, and when investigations do attribute fault, the findings rarely, if ever, isolate individual or human failure.

Another reason why the culture of bravery has lessened over time in the nuclear power and aviation industries but not in the HSE is related to the nature of their career paths. Many nuclear power plant operators are hired with military experience, most often involving participation in U.S. Navy nuclear programs, which have a safety culture with documented policies that demonstrate valuing safety above other priorities and continual

¹⁹⁷ Van Erp, *Safety Culture and the Accident at Three Mile Island*, 161.

improvements in safety techniques and equipment.¹⁹⁸ The nuclear field also hires operators without a military background who have completed intensive college or vocational training.

A similar hiring pool is available to careers in air traffic control. Some have military experience, often in the air force or similar military work, and others earn career opportunities with college and vocational training. A related key point is that air traffic and nuclear power control room operators are careers with a history that is sufficiently long and that have employed individuals who have aspired to these positions. In comparison, the command centers of the HSE are still fledgling operations staffed with personnel who never had long-term goals to become command center operators and who tend to come from a range of military branches with a strong culture of bravery historically, as well as today. Further, HSE command center operations represent a career field logically fitting and appealing to patrol officers or detectives, which are positions that are still firmly rooted in a bravery culture. The author argues that the HSE's relatively short existence and its career lineage tie to high bravery culture roots contribute to its reduced focus on safety and human error compared to the other two fields. In addition, related and most unfortunate, the kind of work in the HSE command center is neither patrol nor investigative in nature, yet HSE command center operators tend to come from those two types of jobs, which have minimum safety and human error standards or regulations. In short, culture is more difficult to establish in an emerging field staffed with personnel who tend to come from fields with strong and existing bravery cultures, which he has witnessed repeatedly as a participant observer of the HSE.

In summary, the longer history, and established career paths, nature of the adversary, and public pressure to avoid catastrophes led the aviation and nuclear energy industries to develop a strong culture of safety. The HSE is different from those two fields in all those regards, which has contributed to its persistent culture of bravery and lack of interest in addressing human error issues. The next section highlights additional

¹⁹⁸ David R. Liskowsky, *Biological Rhythms: Implications for the Worker* (Washington, DC: U.S. Government Printing Office, 1991), 143, <https://www.princeton.edu/~ota/disk1/1991/9108/9108.PDF>.

differences between the HSE and the other two fields' operations, particularly in regards to scheduling control room staffs.

D. COMPARATIVE ANALYSIS OF THE THREE FIELDS' CENTERS

In this section, the author compares the three fields with regard to policies, practices, and mandates relevant to human factors and errors imposed upon the comparison groups' command center personnel. This section compares three main elements: (1) fatigue mitigation scheduling, practices, and related policies, (2) fatigue detection and mitigation training of supervisors and line staff, and (3) the focus of fatigue and human error in labor contracts. A comparative discussion of the role of the public documentation of human error concludes this section.

1. Fatigue Mitigation Scheduling and Procedures

In all three of the comparison work environments, staffing is required 24 hours per day and 365 days per year, which inherently presents human fatigue problems. The nuclear power plant industry is the only one of the three comparison groups that schedules "outages," defined by the NRC as "the shutdown of a generating unit, transmission line, or other facility for inspection, maintenance, or refueling, which is scheduled well in advance."¹⁹⁹ If an outage cannot be planned at least 48 hours in advance or postponed a minimum of two days, it is considered to be a forced outage.²⁰⁰ Forced outages are emergencies related to equipment breakdowns, the unavailability of parts, human error, and fuel issues.²⁰¹ The ability to plan an outage or to force one in an emergency is an important distinction in this comparative analysis. Maintenance programs of this type demonstrate an understanding of mechanical limits of all types and almost eliminate catastrophic equipment failures.²⁰² The existence of the shutdown plan

¹⁹⁹ "Glossary—Outage (Scheduled)," last reviewed/updated, June 21, 2016, <http://www.nrc.gov/reading-rm/basic-ref/glossary/outage-scheduled.html>.

²⁰⁰ "Glossary—Outage (Forced)," last reviewed/updated June 21, 2016, <http://www.nrc.gov/reading-rm/basic-ref/glossary/outage-forced.html>.

²⁰¹ Ibid.

²⁰² "Operations and Maintenance Best Practices Guide," 5–4, 2016, <http://energy.gov/eere/femp/downloads/operations-and-maintenance-best-practices-guide>.

and practice communicates an understanding of the risk of fatigue and critical value of prevention. It, in a sense, provides a broad road map for plant operators to prevent a disaster, including those of the human factor variety, and reminds those who work in the field that all factors that can lead to problems need consideration.

Air traffic control towers and centers in this comparative analysis generally do not schedule outages. Rare emergencies have closed all or part of the national air space, such as a 2014 air traffic control equipment fire in Chicago, and the terrorist attacks of 9/11. While it is highly unusual to shut down the national air space for scheduled outages, it is technically possible, just as it is for nuclear power plants. The HSE on the other hand is different. In society, states of emergency or martial law can be declared and curfews can be imposed, but no comparable element of society corresponds to a nuclear reactor or commercial airplane. In fact, if it were possible to cause an “outage” of the criminal element, it would make sense to do that. While HSE command centers have not arrived at the point at which they are critical to daily field operations, during emergencies, even agencies without full-time command centers establish them temporarily. When this situation happens, they face unique human factor challenges because they are considered critical and cannot be easily taken offline for rest. Moreover, their urgent and temporary set up often means they do not have policies and practices in place to address human error risks.

One of those risks is staff scheduling, particularly the issue of down time or rest periods for staff. A review of the documentation on the number of people working in a day-to-day or in non-emergency conditions demonstrates that rest-period practices are similar in both the nuclear power and HSE fields, with aviation being quite different in size and scope. Outside of the command center environment, the HSE has the most employees working around the clock in all three fields. This information is important because those employees provide an extremely large feeder pool for HSE command centers. Further, well-established non-command center staffing plans (e.g., for field officers and agents), have infiltrated the HSE command centers in some cases, contrary to human factors research. Their historical scheduling policies and practices fail to consider the role of human error and fatigue, which has carried over to HSE command centers.

Hence, compared to aviation and nuclear power, the HSE is the weakest in the consideration of rest periods as a way to mitigate fatigue during lengthy work schedules, a comparison pattern similar to other dimensions of command center employee scheduling.

The workload or potential workload in each of the comparison fields dictates staffing levels and schedules, which, for all three fields, are to varying degrees largely predictable. Air traffic control centers are organized to manage special demands related to holidays, special events, and weather. The schedules worked by air traffic controllers are a balance of what the government wants and what works for the local authorities and employees. As a result, the larger regulators at the federal level set broad guidelines, but individual air traffic control centers have local control, which results in most air traffic controllers working a compressed five-day work week into only four days. From a fatigue management perspective, this practice only meets minimum standards and is not particularly beneficial to the prevention of fatigue. The broad regulations in air traffic control prohibit employees from working more than six consecutive days and from working more than 10 consecutive operational hours; also, controllers must be off for a specified number of hours before starting a shift.²⁰³ These rules were intended to address the issue of cumulative fatigue and to ensure restorative rest between shifts, but a 2012 FAA self-initiated audit found 8,973 violations of the between-shift rest requirements between January 1, and May 20, 2012. Most of the violations however (73 percent) were minor, generally amounting to 15 or fewer minutes short of the minimum required time off. Hence, the majority of aviation violations are minor and related to the required minimum time between shifts.²⁰⁴ The 2012 audit identified two more serious violations of the rule that prohibits working in excess of six consecutive days. Still, the audit determined that in practice, air traffic control work rules intended to prevent fatigue are often considered flexible or are ignored entirely with little, if any, administrative consequence. One example is an electronic timekeeping system that alerts the user to

²⁰³ Federal Aviation Administration, *FAA's Controller Scheduling Practices Can Impact Human Fatigue, Controller Performance, and Agency Costs*.

²⁰⁴ *Ibid.*, 17.

inadequate rest that can be overridden by the user without supervisory approval or a predictive fatigue assessment.²⁰⁵ Hence, despite rules and equipment created to mitigate fatigue, the actual adherence to them is not consistent in the aviation control centers.

In comparison, nuclear power plant operators are required by regulation to conform to minimum scheduling standards. Similar to the rules in aviation, these staffing rules were designed to prevent a worker from being required to fill a vacant position in a fatigued condition or in a condition where fatigue is predicted. Unlike aviation, nuclear power plant managers must approve a waiver to exceed the work hour limitations and only when exceeding the hours is “necessary to mitigate or prevent a condition adverse to safety,” or “to maintain site security.” Further, prior to granting a waiver, a properly trained manager would be required to conduct a “predictive fatigue” assessment of the employee being asked to work beyond regulation hours. A predictive assessment is not only intended to determine whether the worker is currently fatigued, but also to determine whether the employee will become fatigued over the anticipated work period. The other two comparison fields do not have this type of built-in assessment policy.

An issue related to staff scheduling issues is the allowance of intentional sleep or napping. Although unintentional sleep is officially not allowed in any of the work environments studied, napping during breaks is affirmatively permitted in both nuclear energy and aviation, but not in the HSE command centers studied. Despite some early confusion on more recent rule changes, air traffic controllers are permitted to counter fatigue by napping in non-operational settings and while on breaks. The same is true for workers in nuclear power plants. Unlike these two fields, napping is trickier for employees at the HSE command centers. None of the documents available for this thesis indicated evidence that intended, restorative napping is authorized in the HSE and related agencies. In practice, however, it likely does occur with approval, as the present author has permitted rare and exceptional situations wherein personnel subjected to extremely long extensions to their regular tour of duty were encouraged to nap. It is a common sense or practical solution to the objective symptoms of sleep deprivation when the

²⁰⁵ Federal Aviation Administration, *FAA’s Controller Scheduling Practices Can Impact Human Fatigue, Controller Performance, and Agency Costs*, 17.

immediate danger of a particular situation (e.g., fire, flood, earthquake, or riot) has passed, but shift relief is not yet available.

Another consideration related to scheduling is moonlighting, generally a matter covered in CBAs. Limitations on where an employee can moonlight are based largely on conflicts of interest and liability. How long a person can work is a matter of fatigue mitigation. None of the three comparison fields' work environments strictly prohibits moonlighting, but the prevalence of potential work related to the HSE makes moonlighting a more serious concern, as the opportunities are nearly endless for officers (e.g., private event security jobs). The LAPD is somewhat unique among public safety agencies in that limits to the number of hours an employee may work in any capacity off-duty have been imposed. Prior to the economic downturn in 2008, most LAPD officers were prohibited from working more than 20 hours in an off-duty capacity. However, to help offset the significant reduction in allowable overtime in 2008, the allowable hours per week of off-duty employment increased to 30 hours. While not specifically stated as a fatigue mitigation strategy, it is widely understood that limiting off-duty employment promotes fitness for regular duty, but the HSE has largely ignored that strategy over the last eight years.

Unlike the HSE, nuclear power plant workers may find off-duty work, but it is unlikely that the work will be in the nuclear field, as moonlighting options within the industry are nonexistent. The research for this paper suggests that off-duty work is not an issue for both the nuclear power industry and aviation. During the illegal air traffic controllers strike in 1981, the newly unemployed workers could not find work in air traffic control except outside of the United States. It appears that air traffic controllers still cannot readily find local work in their field. In short, while all three fields require workers be fit for duty, the issue of moonlighting is not so serious in the aviation and nuclear power, but in the HSE, it is a huge issue in light of the boundless opportunities and policies that allow up to 30 hours of off-duty work; limitations to moonlighting that are not substantial and not strict enough to address fatigue risk.

Another scheduling-related issue is the prevalence of compressed work schedules. When people work a compressed work schedule, they reduce the number of commutes to

work and increase the number of consecutive days off, which makes this type of schedule popular across fields. A study conducted by the *Los Angeles Times* demonstrated a correlation between long commutes and the ability to compress work weeks, which means employees in these instances are working very long days and driving very far, which is risky from a fatigue perspective.²⁰⁶ Also, in the current author's experience, the compressed work week has encouraged living greater distances from the worksite. This situation is potentially problematic in all three fields because the regulations or policies related to the duty-day start when the employee is on site or when they clock in does not take into account driving time. For an employee who has a two-hour commute to work, a contributor to fatigue factor is hidden to the supervisor or commander. Unintended consequences of compressed work schedules, such as the hidden fatigue caused by long commute times, could be an area for additional research, to be discussed more in Chapter VII, and needs to be considered for fatigue detection and training, as described in the next section.

2. Fatigue Detection and Training

Intentional policies or training on fatigue detection may seem like obvious considerations for the HSE, but in the author's role as a participant observer, he has witnessed public safety supervisors advising their staffs on many occasions to walk around, splash some cold water on their face, or consume an energy drink or coffee to stay alert. Finding someone "on the nod" requires little skill, but less obvious signs of fatigue may be more difficult to identify, and adopting an attitude and procedure for detecting fatigue necessitates training. The HSE has neither the procedures nor training in place for predicting or detecting fatigue and related conditions that could lead to human error.

In contrast, the NRC and the FAA lead the way with regard to fatigue mitigation detection and training. Pursuant to Title 10, Code of Federal Regulation Part 26.29, nuclear plant supervisors must receive comprehensive initial and ongoing refresher

²⁰⁶ Emily Alpert Reyes and Doug Smith, "Most L.A. City Employees Don't Live in L.A., Times Analysis Finds," *Los Angeles Times*, June 17, 2014, <http://www.latimes.com/local/la-me-out-of-town-20140608-story.html>.

training on fitness for duty protocols. Supervisors must be able to observe and detect performance degradation, indications of impairment, or behavioral changes, as well as to take appropriate action, including referrals to employee assistance programs, assigning rest periods, and formal discipline.²⁰⁷ Similarly, for aviation as a whole, the FAA has produced and made publicly available training videos (e.g., Grounded²⁰⁸), online and interactive courses (e.g., Fatigue Countermeasure Training²⁰⁹), and Title 14, Code of Federal Regulation Part 117, which is aviation's counterpart to the NRC regulation cited previously in 10 CFR, Part 26.29. In the same way that the NRC programs apply mainly to the licensed control room operators, the FAA fatigue videos, training, and regulations apply mainly to pilots and air crews. The FAA has made information regarding fatigue easily available to those working in aviation, which includes control center staff, likely because there are over one-half million licensed pilots and over three-quarter million licensed non-pilot employees, all of whom play a role in aviation and public safety.²¹⁰ The HSE does not have comparable tools or processes nor a universal fatigue mitigation program or guidelines. In the areas where a body of research is related to fatigue, the scope is narrowly focused on the police officer and field shift work, and not on HSE command center operations.

3. Fatigue Mitigation in Law, Regulations, and Labor Contracts

Fatigue mitigation in law, regulations, and labor contracts is important because it demonstrates a high level of agreement that a serious problem exists and a desire to prevent it. Nuclear energy and aviation are at similar stages of development regarding overall regulations. However, only air traffic control mentions fatigue in its labor contract, which sets it apart from both nuclear energy and the HSE. The HSE is even further apart because aviation and nuclear energy have moved toward a culture of safety

²⁰⁷ "10 CFR 26.29 Training," last reviewed/updated December 2, 2015, <http://www.nrc.gov/reading-rm/doc-collections/cfr/part026/part026-0029.html>.

²⁰⁸ Federal Aviation Administration, "Grounded, FAA Fatigue Mitigation Training," video, 2011, <https://www.faa.gov/tv/?mediaid=400>.

²⁰⁹ "Course Overview—Fatigue Countermeasure Training," 2016, <https://www.faasafety.gov/gslac/ALC/CourseLanding.aspx?cID=174>.

²¹⁰ "U.S. Civil Airmen Statistics," last modified April 25, 2016, https://www.faa.gov/data_research/aviation_data_statistics/civil_airmen_statistics/.

and consider fatigue mitigation a priority, which is not presently evident in the evolution of the HSE.

Air traffic control as a group initially appeared to be the most advanced in this comparison in regards to regulations because for the most part, it is a unified operation, which means that controllers at centers and major towers are government employees, represented by a single labor union. While low-volume airport towers are staffed by contract controllers, they must also conform to all training standards.²¹¹ They handle a similar number of operations per hour and operate with far fewer controllers compared to a high volume airport staffed by FAA controllers.²¹² While contract controllers report fewer safety incidents, it is important to note that they are not required to participate in the Air Traffic Safety Action Program (ATSAP) in place at all FAA facilities. However, they are encouraged to report safety incidents and operational concerns voluntarily.²¹³

In aviation as a whole, fatigue is a primary concern for both management and labor unions, as expressed in labor contracts and various regulations. Nuclear power may appear to be at a disadvantage to aviation in fatigue mitigation because nuclear power centers exist in a complex partnership of private and government owners, private properties, and different labor unions, which represent nuclear and non-nuclear workers. However, nuclear power has the potential to be the strongest in fatigue mitigation due to its relatively small work force size, small number of physical plants, and the fact that in the United States, nuclear power represents under 20 percent of the total electricity generated. Safety and fatigue mitigation has more readily been made a priority because it is manageable and since nuclear power is not the only game in town, it is a competitive field, which is very different from air traffic control in aviation. Having a competitive edge on safety allows nuclear power to remain a leading provider of energy to the public.

²¹¹ Calvin L. Scovel III, *Statement before Congress: Update on the Safety and Cost Aspects of the Federal Aviation Administration's Contract Tower Program* (Washington, DC: Department of Transportation, 2012), 2, <https://www.oig.dot.gov/sites/default/files/Contract%20Tower%20Hearing%20Statement%5E7-18-12.pdf>.

²¹² Office of Inspector General, *Audit Report: Contract Towers Continue to Provide Cost-Effective and Safe Air Traffic Services, but Improved Oversight of the Program Is Needed* (FAA Report: AV-2013-009) (Washington, DC: Federal Aviation Administration, 2012), 5, <https://www.oig.dot.gov/sites/default/files/FAA%20Federal%20Contract%20Tower%20Program%20Report%5E11-5-12.pdf>.

²¹³ *Ibid.*, 2.

In addition to needing to maintain a competitive edge, all U.S. nuclear power operators are entirely dependent on the federal government because only the federal government can own special nuclear material needed for a reactor and issue a license to operate a reactor.²¹⁴ Therefore, non-compliance with regulations, including fatigue mitigation, comes with a high price for any nuclear control center. The level of regulation has been exceptionally strong in the nuclear field, as reflected in the fact that every facility, whether public or private, has a “resident” NRC inspector. According to the NRC, “resident inspectors live near the nuclear power plant where they are assigned,” and “they maintain offices at the plant during regular business hours and spend a portion of their time at the plant during weekends and evenings.”²¹⁵ No other work environment in the present study has this same level of monitoring or oversight.

In this comparative analysis, aviation is more similar to the nuclear power industry than it is to the HSE in regard to regulations and laws. Specifically, just as the federal government maintains strict controls on the ownership of special nuclear material, licenses nuclear operators, and approves the design and construction of nuclear power plants, since the passage of the Air Commerce Act of 1926, only the federal government can certify aircraft and pilots,²¹⁶ which means federal regulations and guidelines address issues of safety, including fatigue and human error. Further, aviation has benefitted from the tremendous amount of research conducted on pilot and air crew fatigue, which has resulted in federal air traffic controller and pilot fatigue policies, and higher priority placed on human error by the U.S. Department of Transportation. In fact, the FAA posts publicly accessible fatigue mitigation training with the stated purpose of benefiting all high-consequence assignments.

In comparison, the command centers of the HSE are the weakest of this paper’s three comparison groups with regard to formal regulations and labor contracts that

²¹⁴ U.S. Atomic Energy Commission, *Atomic Energy Act of 1946* (Washington, DC: U.S. Department of Energy, 1946), 6, <https://www.osti.gov/atomicenergyact.pdf>.

²¹⁵ “Backgrounder on Oversight of Nuclear Power Plants,” last reviewed/updated May 18, 2016, <http://www.nrc.gov/reading-rm/doc-collections/fact-sheets/oversight.html>.

²¹⁶ Federal Aviation Administration, *The First U.S. Federal Pilot License* (Washington, DC: Federal Aviation Administration, n.d.), accessed September 9, 2016, https://www.faa.gov/about/history/milestones/media/first_pilots_license.pdf.

address fatigue mitigation. In fact, this author found no information on fatigue mitigation training specific to the command center work environments of the HSE. At the present time, nothing indicates that HSE command centers are viewed as essential to the effectiveness of public safety field operations; in fact, the absence of any significant publicity for either notable successes or failures in HSE command centers can be viewed as evidence that HSE command centers are supplemental and not essential to crime fighting efforts and matters of community relations and human error (especially those involving deadly force) among field officers. In other words, the public has never expressed concerns that fatigue or human error in command centers might lead to problems in the field or community. Hence, it follows that related rules and regulations are essentially nonexistent for command center work, although some regulations and the HSE focus on other components of policing.

Airport baggage screening is one of those policing areas where fatigue is a consideration. Based on the numerous audits of professional baggage screeners,²¹⁷ and the personal observations by this author of fatigue mitigating baggage screener post rotations (i.e., limits to “time on task”), and the implementation of technologies, reducing human error is a top priority for baggage screeners.²¹⁸ However, considering fatigue in baggage screening may be due to it being a type of policing that occurs primarily at airports, and is likely more subject to FAA guidelines and pressures. That station speaks further to the point that the FAA and aviation in general have strong fatigue mitigation policies, laws, and practices.

E. PUBLIC RECORD OF HUMAN ERROR

The patterns of similarities and differences in public reporting of human error among the three comparison groups clearly reflect the patterns of their policies, regulations, and practices. Hence, although accidents and near accidents in all three

²¹⁷ “Component: Transportation Security Administration (TSA),” accessed December 7, 2016, https://www.oig.dhs.gov/index.php?option=com_content&view=article&id=22&Itemid=46.

²¹⁸ Department of Homeland Security, *Advanced Integrated Passenger and Baggage Screening Technologies* (Washington, DC: Department of Homeland Security, 2015), <https://www.dhs.gov/sites/default/files/publications/Transportation%20Security%20Administration%20-%20Advanced%20Integrated%20Passenger%20and%20Baggage%20Screening%20Technologies%20-%20FY%202015.pdf>.

comparison groups occur on a regular basis, the HSE's reporting of them is dissimilar from the other two fields' efforts to do so. Not surprisingly, the practice of making accidents and near accidents a part of the public record is considerably more common in the fields of nuclear energy and aviation. In fact, both the NRC and the FAA have clear policies and practices on reporting errors and accidents and have public websites that post records of them and their related investigations. Likewise, the HSE has an online, centralized location for accidents and near accidents for its command centers, but it is difficult for the public to find it. Policies and practices regarding reporting of errors by HSE agencies do not appear to be clear cut. The current author has observed a sizeable variation in the transparency of human error reporting of the fields in this comparative analysis.

While public air traffic control centers openly publish human error information, the small number of private companies that run air traffic control operations reports considerably lower numbers of errors. The labor union for the federally employed controllers has contended that these lower numbers result because private companies have a contract at stake and are less likely to report errors, in essence, placing their contract above safety.²¹⁹ The nuclear power industry is highly transparent in regards to human error reporting. The NRC publishes records of accidents, near accidents, and dangerous circumstances. Some of the most notable releases of public information pertain to dangerous situations related to fatigue. For example, in 1987, the NRC issued an order for the Peach Bottom Nuclear Facility to stop generating electricity. In the order, which was the subject of many media reports following its release, indicated that "At times during various shifts, in particular the 11:00 p.m. to 7:00 a.m. shift, one or more of the Peach Bottom operations control room staff (including licensed operators, senior licensed operators and shift supervision) have for at least the past five months periodically slept or have been otherwise inattentive to licensed duties."²²⁰

²¹⁹ Mike Ahlers, "Study: Private Airport Towers as Safe, Cheaper than Government Towers," *CNN Travel*, 2012, <http://www.cnn.com/2012/11/20/travel/air-traffic-control-towers/>.

²²⁰ Victor Stello Jr., *Order Suspending Nuclear Power Operation—Peach Bottom Power Plant* (Washington, DC: United Nuclear Regulatory Commission, 1987), <http://www.nrc.gov/docs/ML0113/ML011370002.pdf>.

The FAA reports far more accidents and near accidents than either of the other two fields in this comparison, which is almost certainly due to the fact that aviation operations are massive and involve endless operational decisions on a daily basis that could potentially result in a reportable incident. It is also likely reflective of the industry's concern for fatigue mitigation. While some examples of public records of human error in the HSE non-command center work certainly have been reported, such as those made by baggage screeners and line-level police officers, public records of human error reports for command centers and other types of HSE work are rare, and where they do exist, they are vague at best.

Public confidence and adverse public sentiment tend to drive the need for public disclosure of errors. At present, the potential for civil rights violations in the HSE command center setting is driving the need for its transparency, which more recently drove the development of strict policies on privacy for fusion centers. Still, unlike the other two fields of focus in this paper, the public's concern for HSE's reporting of errors related to fatigue has been minimal, leaving the HSE to ignore easily the likelihood that human error and fatigue are significant contributors to major incidents in law enforcement and to barely mention it in the public record. In short, the lack of HSE's focus on fatigue issues in its command centers is clearly reflected in its lack of commitment to reporting human errors to the public.

F. CONCLUSION

Aviation, nuclear power, and homeland security, while different in scope and purpose, have spawned control room work environments that are remarkably similar. Control rooms or command centers by their very name and definition are designed to maintain control or assert command over an actual or potential loss of control or absence of command. In this comparison, achieving mastery or near-mastery over a non-intelligent adversary, as in the science of manned flight or nuclear power, is key to public acceptance. Mastery over an intelligent adversary as in homeland security is more elusive and not as strongly tied to public acceptance. Yet, fatigue as an adversary is common to

all three fields' work environments, and while having no intelligence of its own, infiltrates human and mechanical systems in a highly predictable ways.

In spite of the predicable nature of fatigue and a large body of knowledge on human factors, the three comparison fields' work environments continue to have policies and work schedules that could contribute to human performance problems, although to differing degrees. Factors, such as historical evolution, large catastrophes, culture of bravery versus safety, and public pressure, among others, have influenced the fields' generation of policies, procedures, and practices over the years. Improvements in the HSE work environment lag behind because unlike the other two fields, a major catastrophe or near catastrophe has not been directly tied to a single human failure, with the possible exception of the September 11, 2001, terrorist attacks, which were primarily attributed to a lack of information sharing. Aviation and nuclear energy experienced rapid change when preceded by a catastrophe or a real potential for catastrophe (i.e., an adverse effect on public confidence) in partnership with technological readiness and a lack of public confidence. Those driving forces have played less of a role in the HSE, although the potential for harm from fatigue is considerable in its command centers. This comparative analysis found several areas for improvement for HSE command center work environments, which are outlined in Chapter VII.

VII. CONCLUSION

A. INTRODUCTION

This paper compared the fatigue mitigation practices of air traffic control, nuclear power, and homeland security in the context of their respective command center work environments to identify both common and best practices, as well as differences, gaps, and weaknesses in the consideration of human error. The analysis was guided by the overarching research question: How do current practices in command center environments of the HSE conform to the scientific understanding of human fatigue, and how can established practices that mitigate human fatigue and related human factor errors found in other high-consequence fields be useful in improving HSE command center environments?

To begin answering the question, a literature review was conducted that highlighted the nature of fatigue and the risks associated with it and related human errors in high-consequence fields, followed first by a discussion of the practices and policies in each of the three fields and second by a close comparative analysis of them. While similarities were found in the HSE's command centers' appearance and public safety functions compared to those of the other two fields, many differences were identified. The HSE's fledgling command centers lack the fatigue prevention policies and procedures that exist in the other two fields' well-established centers. The analysis of the diverse workplace environments led to a grounded theory regarding why disparities in fatigue mitigation practices may exist, which form the foundation for the recommendations proposed in this chapter.

B. RECOMMENDATIONS

Two of the command center work environments (aviation and nuclear energy) are better established in large part because they have been in existence longer and because they have experienced catastrophes directly attributable to failures in the command center environment. An immediate need exists to close the gap between command centers that recognize the body of knowledge on human factors in fatigue and those that do not (i.e.,

HSE). The following recommendations can be accomplished largely with existing resources, recognizing that absent a catastrophe, large increases in budgets and regulations are unlikely. They fall into the categories of training, FFD, technology, and human factor data collection policies.

1. Training

Since the HSE work environment is relatively new, it exists with personnel and practices trained and indoctrinated in a culture of bravery as explained in Chapter VI. Therefore, immediate retraining is warranted for all levels of the HSE command center work force, including line level workers, supervisors, managers, and collective bargaining units. Well-developed and evidence-based training is a recommended first step in neutralizing cultural biases and misconceptions related to fatigue, such as the false belief that fatigue can be overcome by a force of will or that individuals can accurately assess themselves. This proposed training plan is divided into two phases, general awareness and specialized training.

The proposed fatigue-awareness training for the HSE is based largely on the FAA's Fatigue Education and Awareness Training (FEAT),²²¹ and to a lesser degree, the Code of Federal Regulations (10 CFR Part 26, Subpart I, "Managing Fatigue") used by the NRC.²²² Absent a legal requirement for a fatigue-training program, which exists for the FAA and the NRC, the HSE program would be initially voluntary, although the current author advises that a legally binding standard of training be the goal of the HSE. At present, it is recommended that command center directors adopt an existing program or develop a program locally that conforms to the following learning domains:

- Review of agency policies and expectations related to FFD
- Circadian rhythms and the fundamentals of sleep

²²¹ U.S. Department of Transportation, *Operations Specification—A319, Fatigue Education and Awareness Training (FEAT) Program* (Washington, DC: Federal Aviation Administration, 2016), http://www.faa.gov/documentLibrary/media/Notice/N_8900.347.pdf.

²²² Office of Nuclear Regulatory Research, *Fatigue Management for Nuclear Plant Personnel* (Washington, DC: Nuclear Regulatory Commission, 2009), <http://www.nrc.gov/docs/ML0834/ML083450028.pdf>.

- Other causes of fatigue (e.g., stress, sleep disorders, and sleep debt)
- Overview of fatigue mitigation in high-consequence work environments
- Complicating factors (e.g., commuting and moonlighting)
- Fatigue countermeasures (e.g., lifestyle, nutrition, exercise, scheduling, napping).

The second phase of training would be significantly more specialized and is intended to provide methods for management and supervisory personnel to assess individuals for fatigue-related impairment in four basic situations identified by the NRC. The goals of the training are to help supervisors gain expertise in fatigue assessments and skill in taking steps to prevent human error in the command center. This type of training is divided into four components as follows.

- **Fatigue Identification:** This training component refers to situations when a qualified supervisor intervenes *for cause*, which means that a qualified supervisor has detected objective symptoms of fatigue impairment. This training would be similar to existing training for drug or alcohol impairment, and may require supervisors to evaluate employee errors and unintended sleep closely.
- **Self-Declaration.** *Self-declaration* refers to situations in which a command center worker has self-reported as fatigue-impaired. This training component focuses on how to conduct self-assessments and the options for mitigating fatigue, such as ensuring adequate rest prior to and during fatigue-prone shifts or tasks.
- **Post-Assessment Return:** This component to the training applies when a command center worker has returned to work after being identified as unfit for duty based on a prior fatigue assessment. This component focuses on teaching supervisors to assess whether previously fatigue-assessed employees returning to work are ready to work and to monitor them upon return to ensure their readiness for critical assignments.
- **Analysis of Field Incidents:** This component to the specialized training focuses on teaching supervisors and managers how to consider and analyze critical command center related incidents that take place outside of the center itself (e.g., damage to field equipment or serious injury or death to HSE personnel or the public). This training would teach methods for assessing field incidents to determine whether they can be traced back to the dissemination of information or guidance provided by a command center, and when they are linked to command center fatigue or human-related error, and the options for addressing them.

The issue of who should conduct fatigue assessments and how to train them is not only lacking in the HSE, it is also somewhat unclear in the other two fields. The NRC FFD program states that only qualified supervisors may conduct fatigue assessments, but does not define what a “qualified supervisor” is nor does it outline precise minimum training standards to certify supervisory staff as “qualified supervisors.” Key NRC documents indicate that a supervisor conducting a fatigue assessment must have attended at minimum a basic fatigue awareness course and be qualified to perform the duties of the individual to be assessed.²²³ The author recommends that the HSE adopt this policy in addition to requiring the previously outlined trainings. However, this author would also argue that the proposed specialized training exceed the standard currently in place by the NRC and require all HSE supervisors to be professionally trained in conducting fatigue assessments and handling situations in which fatigue has been identified in a front line staff person. It is recommended that professional trainings and certifications be developed under contract with accredited universities or interdisciplinary nonprofit organizations, such as the Human Factors and Ergonomic Society or private training centers compliant with FAA and NRC standards.

2. FFD Programs

It is recommended that the HSE generate a comprehensive FFD program designed for the type of risks known to affect command center work environments that would complement the proposed training programs outlined in the previous section. This recommendation emerges from the previous chapter’s comparative analysis, which identified a gap related to FFD programs in the HSE command center work environment. The HSE would clearly benefit from creating the well-rounded FFD programs evident in aviation and nuclear energy command centers. The gaps in the HSE would be filled through a four-component program that includes (1) updated limits to scheduling (e.g., hours worked and days off), (2) standardized investigations of human-error incidents and near incidents, (3) self-declaration policies, and (4) advanced supervisory training that

²²³ United States Nuclear Regulatory Commission, *Frequently Asked Questions about Fatigue Management Program* (Washington, DC: Nuclear Regulatory Commission, 2016), <http://www.nrc.gov/docs/ML0925/ML092530677.pdf>.

would be integrated into components one and three of the specialized training outlined in the previous section.

Given the earlier discussion of how long work schedules may play a role in fatigue, the first component of the FFD recommendation addresses scheduling. The NRC standard, currently used by licensed nuclear energy personnel, is a model scheduling process because it emphasizes the importance of managing cumulative fatigue while allowing employers the flexibility to offer compressed work-week schedules that are highly desirable to the modern workforce. The NRC standard also brings much needed attention to the concept of cumulative fatigue in high-consequence environments and allows for limited deviations in exceptional circumstances (e.g., unexpected staff shortages and plant emergencies). Hence, it provides a balance between employee preferences and safety regarding fatigue.

Using the NRC model, the recommendation is that the HSE personnel assigned to command center work environments be required to average no more than a 54-hour work week (i.e., average based on a rolling six-week period). The NRC 54-hour limit is based on findings of research on the cumulative effects of fatigue and has proven useful to preventing fatigue-related errors in nuclear power command centers. In addition to the 54-hour limit, HSE command center personnel would be required to have one, two, or three days off each week depending on the number of hours worked per day (e.g., 8, 10, or 12) to provide time for restorative rest. Additional, related guidelines should be developed to provide further safeguards, such as limits on the total number of hours worked in specified periods (e.g., 16 within any 24-hour period, 26 in any 48-hour period, and 72 in any 7-day period²²⁴). As with the NRC model plan, the HSE plan must have emergency exceptions that permit supervisors to authorize deviations to the limits in unusual circumstances, such as unexpected absences of personnel and manmade or natural emergencies. Although the FAA model has similar provisions, deviations from policies can occur without supervisor approval, making the NRC model more desirable for the HSE.

²²⁴ “10 CFR Part 26—Fitness for Duty Programs.”

The HSE should create a self-declaration process that would be implemented as an intentional precursor to a culture shift and ensure FFD. Self-declarations in FFD programs require that individuals notify a supervisor when they are presently or about to become unfit for duty. This requirement is different from taking a personal day off or “going home sick,” as the supervisor would be required to conduct a fatigue assessment, and if necessary, remedy the problem. In the HSE work environment, a supervisor might choose to monitor the concerned employee’s work product more closely, provide an opportunity for restorative rest, or arrange for relief. The current author’s view is that self-declarations would unlikely occur in a bravery culture, as discussed in Chapter VI, and creating clear policies and procedures for it are crucial for the HSE. Self-declarations are known to more likely occur in a safety culture, such as that of the nuclear power industry, especially when the FFD program and the self-declaration provisions are considered “protected activity,” meaning that their use cannot be cause for adverse employment action.²²⁵

3. Technology

The third type of recommendation pertains to the leveraging of technology to improve human performance, especially fatigue mitigation. By their very design and purpose, HSE command centers are at the forefront of computerized analytics. The advanced technology of the HSE can be leveraged to predict, prevent, and mitigate fatigue-related human errors. As a start, technology that efficiently identifies fatigue exists in other fields and can be readily adopted by the HSE. For example, developed first for professional drivers, commercially available and scientifically validated devices can alert users and their supervisors to fatigue and sleepiness based on biometrics, such as the “Eagle Portable” from the company “Optalert.”²²⁶ “Optguard,” developed by the Guardvant Corporation, is a similar device that measures eyelid and head position among

²²⁵ United States Nuclear Regulatory Commission, *Self-Declarations of Fitness for Duty* (Washington, DC: United States Nuclear Regulatory Commission, 2002), 1–4, <http://www.nrc.gov/reading-rm/doc-collections/gen-comm/reg-issues/2002/ri02007.pdf>.

²²⁶ “Eagle PORTABLE Drowsiness Detection System,” accessed December 7, 2016, <http://www.optalert.com/portable-drowsiness-detection>.

other factors to predict fatigue and tiredness accurately.²²⁷ Furthermore, many technology companies, such as Qualcomm, are providing long-haul trucking carriers with electronic logging devices (ELDs) that display and transmit critical data to prevent driver fatigue, enhance safety, and mitigate risk. These same technologies could be used with few, if any, modifications to mitigate fatigue in a command center setting. Further, technology will be useful to the HSE during critical incidents when personnel are working longer shifts, as it can alert employees and management to the need for extra oversight in critical decisions.

4. Collection and Use of Human Factor Data

In conjunction with the training recommendation, it is advised that significant human error and near-human error incidents be subjected to a standardized investigation and that key data be collected and analyzed. Although what is deemed a significant human error or incident may vary according to local policy, standardized investigations should be conducted for both actual and near-incidents and be documented regardless of whether actual death, injury, or damage occurred to provide the HSE with useful information.

This recommendation would have a two-fold corrective effect on the HSE. First, human factor data would begin to be compiled for the command center work environment nationally. With the limited exception of the LAPD, no known instances of data being compiled for accuracy and safety in the HSE command center work environment are available. By conducting standardized investigations into human-error incidents and near incidents, valuable and comprehensive data potentially pointing to fatigue or other factors in command center work environments would be available for analysis. The analysis of these data could be used to improve supervisors' in-the-moment, case-by case decisions about scheduling. Secondly, the focus on human factors could have a long-term impact on policies related to scheduling, automation, supervision, commuting, and moonlighting. In other words, future modifications to command center

²²⁷ "Opguard: How It Works," accessed December 7, 2016, <http://www.guardvant.com/solution/opguard/opguard-how-it-works/>.

structures and policies would be data-driven and evidence-based; thereby, helping to prevent fatigue-related catastrophes. For example, if the evaluation of collected information revealed that moonlighting was associated with a disproportionate number of errors or near-errors, limitations or additional review of personnel in those situations could be implemented.

C. FUTURE RESEARCH

Little doubt exists that fatigue is a fragility of the human condition and that it affects members of the HSE. This research coined the term “bravery culture” and asserted that all three comparison fields started in the bravery culture, albeit to differing degrees. A worthy endeavor for future research is the identification of effective methods for facilitating the shift from cultures of bravery to cultures of safety, particularly in workplace environments in which the overt adversaries are human. This element of future research would identify the factors in cultures of bravery that make the shift to a culture of safety difficult. A study of a culture shift (e.g., bravery to safety) would necessarily bring attention to human performance and adversaries to optimal human performance, such as fatigue.

This comparative analysis also revealed a need for research into a particular type of fatigue known as automation fatigue. Command centers are technology-rich environments that include walls of broadcast television screens and closed circuit television monitors. The personnel tasked with monitoring the screens often began working in the HSE when monitoring involved a single two-way radio. Today, these same personnel find themselves monitoring a great deal of visual technology (e.g., computer and television monitors) that has automated many processes. Research needs to determine whether or at which point human performance related to lengthy visual monitoring suffers. This type of future research could lead to better practices, such as time limits on the important, but mundane, or the most rigorous electronic detection tasks, particularly visual ones, such as those conducted by baggage screeners or HSE command center staff who continuously watch large screens.

The final recommendation for additional research pertains to electronic devices used to measure the quality and quantity of sleep. Readily available consumer grade devices are capable of measuring a range of sleep variables. Understanding their effectiveness in the workplace is worthwhile in addition to exploring the relationship between the amount and quality of sleep and performance of various common command center or workplace tasks. For example, longitudinal studies that include large samples of high-consequence workplace employees, including shift workers, who consent to electronic monitoring of sleep habits over time, may provide insights into the correlation between various patterns of sleep or sleep habits and actual workplace performance, including decision making and accuracy. These research findings would provide the scholarly community with a clearer understanding of fatigue impacts while having practical implications for HSE policies, particularly those relevant to restorative rest and time off between shifts.

D. CONCLUSION

The command centers of today and of the foreseeable future will have humans in the loop, and humans make mistakes. Research has demonstrated that they make more mistakes when they are fatigued. Fatigue as an adversary is common to all three fields' work environments, and while having no intelligence of its own, infiltrates human and mechanical systems in a highly predictable ways. The present comparative analysis of the fields of nuclear power, aviation, and homeland security revealed that in spite of this predictability, current policies and work schedules appear to exacerbate the problem more so in HSE command centers in comparison to those in the other two fields. Factors, such as historical evolution, large catastrophes, culture of bravery versus safety, and public pressure, among others, have influenced all three fields' generation of policies, procedures, and practices over the years. Unlike homeland security, aviation and nuclear energy experienced rapid change in fatigue considerations due to catastrophe or the real or perceived potential for catastrophe in partnership with technological readiness and a lack of public confidence. While it is necessary to wait for some technology to be ready, a set of technological advances already are available that can be utilized by the HSE and other high-consequence fields. Unfortunately, often the impetus for adopting their use

and funding are sometimes dependent on the real or perceived fears of the public. Still, waiting for a catastrophe to begin the process of change in the HSE simply does not make sense.

To address the HSE's problems related to its culture of bravery and related lack of focus on human error mitigation, several recommendations were made that focused on fatigue mitigation training, FFD programs, leveraging technology, and capturing data. The grounded theory is that the HSE command center work environments do not have an adequate regard for fatigue mitigation principles for several notable reasons. The HSE command centers have not yet experienced a catastrophe adequate to serve as a catalyst for change, and in their fledgling state, HSE command centers remain steeped in a culture resistant to change. The bravery culture is resistant to change because the HSE faces a uniquely intelligent adversary. The need for change however remains significantly urgent, and if addressed, will serve the HSE in improving wellness, safety, efficiency, and effectiveness. Improving fatigue mitigation and the overall regard for human factor principles will also demonstrate that the HSE is committed to improving critical human performance, which is particularly important in cases involving lone wolf terrorism and deadly force resulting in mounting racial tension.

LIST OF REFERENCES

- Ahlers, Mike. "Study: Private Airport Towers as Safe, Cheaper than Government Towers." *CNN Travel*, 2012. <http://www.cnn.com/2012/11/20/travel/air-traffic-control-towers/>.
- Åkerstedt, Torbjorn, P. Fredlund, M. Gillberg, and B. Jansson. "A Prospective Study of Fatal Occupational Accidents—Relationship to Sleeping Difficulties and Occupational Factors." *Journal of Sleep Research* 11, no. 1 (2002): 69–71. doi: 10.1046/j.1365-2869.2002.00287.x.
- Alfaro-Gonzalez, Lydia, R. J. Barthelmes, Christina Bartol, Michael Boyden, Thomas Calderwood, Daniel Doyle, and Jacob Green, Erin Herro, Taylor Johnson, Katelyn Lawrenz, Katharine McMaster, Margaret Nencheck, Neil Noronha, Lee Smith, Kathleen Walsh, Letitia Wu, and Kaila Yee. *Report: Lone Wolf Terrorism*. Washington, DC: Georgetown University, 2015. <http://georgetownsecuritystudiesreview.org/wp-content/uploads/2015/08/NCITF-Final-Paper.pdf>.
- Amendola, Karen, David Weisburd, Edwin Hamilton, Greg Jones, Meghan Slipka, Anneke Heitmann, Eliab Tarkghen, Christopher Ortiz, and Jon Shane. *The Impact of Shift Length in Policing on Performance, Health, Quality of Life, Sleep, Fatigue, and Extra-Duty Employment*. Washington, DC: National Institute of Justice, 2012. <https://www.ncjrs.gov/pdffiles1/nij/grants/237330.pdf>.
- Arand, Donna L., and Michael H. Bonnet. *We Are Chronically Sleep Deprived*. Dayton OH: American Sleep Disorders Association and Sleep Research Society, 1995. https://www.researchgate.net/profile/Michael_Bonnet/publication/14456961_We_are_chronically_sleep_deprived._Sleep_18_908-911/links/09e41508ecb8bb804000000.pdf.
- Audit Division. *Categorical Use of Force Process Audit*. Los Angeles: Los Angeles Police Department, 2014. http://www.lapdpolicecom.lacity.org/072214/BPC_14-0285.pdf.
- Bajakal, Naina. "The Rise of the Lone Wolf Terrorist." *Time*, October 23, 2014. <http://time.com/3533581/canada-ottawa-shooting-lone-wolf-terrorism/>.
- Barger, Laura K., Brian E. Cade, Najib T. Ayas, John W. Cronin, Bernard Rosner, Frank E. Speizer, and Charles A. Czeisler. "Extended Work Shifts and the Risk of Motor Vehicle Crashes among Interns." *New England Journal of Medicine* 352, no. 2 (2005): 125–134. doi: 10.1056/nejmoa041401.

- Basner, Mathias, Joshua Rubinstein, Kenneth M. Fomberstein, Matthew C. Coble, Adrian Ecker, Deepa Avinash, and David F. Dinges. *Fatigue and Threat Detection*. Philadelphia: University of Pennsylvania School of Medicine, 2008. <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2542965/pdf/aasm.31.9.1251.pdf>.
- Bennett, Hugh H. *Soil Conservation*. New York: McGraw-Hill Book Co., 1939.
- Bigley, Gregory A., and Karlene H. Roberts. “The Incident Command System: High-Reliability Organizing for Complex and Volatile Task Environments.” *Academy of Management Journal* 44, no. 6 (2001): 1281–1299. doi: 10.2307/3069401.
- Carskadon, Mary A., Charles A. Czeisler, William C. Dement, David F. Dinges, R. Curtis Graeber, and Merrill M. Mitler. *Catastrophes, Sleep, and Public Policy*. Emmitsburg, MD: National Emergency Training Center, 1988.
- Center for National Truck Statistics. *Truck and Bus Accident Factbook 1994*. (Report no. UMTRI-96-40). Washington, DC: Federal Highway Administration Office of Motor Carriers, 1996.
- Civil Aeronautics Board. *TWA—UAL Accident Investigation Report Grand Canyon Arizona*. Washington, DC: Civil Aeronautics Board, 1957. http://lessonslearned.faa.gov/UAL718/CAB_accident_report.pdf.
- Congress. *Intelligence Reform and Terrorism Prevention Act of 2004*. Washington, DC: Government Printing Office, 2004.
- . *Pub. L. No. 112-95—FAA Modernization and Reform Act of 2012*. Washington, DC: Government Printing Office, 2012. <https://www.gpo.gov/fdsys/pkg/PLAW-112publ95/pdf/PLAW-112publ95.pdf>.
- Davis, Steven. *Making Your Command Center a Success*. Columbia, MD: DavisLogic, Inc., 1999. <http://www.davislogic.com/Command%20Center%20Article.doc>.
- Decker, Scott, and David Pyrooz. “Gangs, Terrorism, and Radicalization.” *Journal of Strategic Security* 4, no. 4 (2011): 151–166.
- Department of Community and Family Medicine, Duke University School of Medicine. “Anatomy of an Error, Definitions of Error.” Accessed December 7, 2016. http://patientsafetyed.duhs.duke.edu/module_e/definitions.html.
- Department of Energy. “Operations and Maintenance Best Practices Guide.” 2016. <http://energy.gov/eere/femp/downloads/operations-and-maintenance-best-practices-guide>.

- Department of Homeland Security. *2011 National Network of Fusion Centers—Final Report*. Washington, DC: Department of Homeland Security, 2012. <https://www.dhs.gov/sites/default/files/publications/2011-national-network-fusion-centers-final-report.pdf>.
- . *2012 National Network of Fusion Centers—Final Report*. Washington, DC: Department of Homeland Security, 2013. <https://www.dhs.gov/sites/default/files/publications/2012%20National%20Network%20of%20Fusion%20Centers%20Final%20Report.pdf>.
- . *2013 National Network of Fusion Centers—Final Report*. Washington, DC: Department of Homeland Security, 2014. <https://www.dhs.gov/sites/default/files/publications/2013%20National%20Network%20of%20Fusion%20Centers%20Final%20Report.pdf>.
- . *2014 National Network of Fusion Centers—Final Report*. Washington, DC: Department of Homeland Security, 2015. https://www.dhs.gov/sites/default/files/publications/2014%20National%20Network%20of%20Fusion%20Centers%20Final%20Report_1.pdf.
- . *Advanced Integrated Passenger and Baggage Screening Technologies*. Washington, DC: Department of Homeland Security, 2015. <https://www.dhs.gov/sites/default/files/publications/Transportation%20Security%20Administration%20-%20Advanced%20Integrated%20Passenger%20and%20Baggage%20Screening%20Technologies%20-%20FY%202015.pdf>.
- . *The 2014 Quadrennial Homeland Security Review*, 2nd ed. Washington, DC: Department of Homeland Security, 2014. <https://www.dhs.gov/sites/default/files/publications/2014-qhsr-final-508.pdf>.
- Embry-Riddle Aeronautical University, Prescott Aviation History Program. *The History of Air Traffic Control*. Video, 2012. <http://commons.erau.edu/aviation-history/9/>.
- Federal Aviation Administration. *Collective Bargaining Agreement between the National Air Traffic Controllers Association AFL-CIO and the Federal Aviation Administration U.S. Department of Transportation October 2009*. Washington, DC: Federal Aviation Administration, 2009.
- . “Course Overview—Fatigue Countermeasure Training.” 2016. <https://www.faasafety.gov/gslac/ALC/CourseLanding.aspx?CID=174>.
- . *FAA’s Controller Scheduling Practices Can Impact Human Fatigue, Controller Performance, and Agency Cost*. (Report Number: AV-2013-120). Washington, DC: Federal Aviation Administration, 2013. <https://www.oig.dot.gov/sites/default/files/FAA%20Air%20Traffic%20Controller%20Scheduling%20Practices%5E08-27-13.pdf>.

- . “Grounded, FAA Fatigue Mitigation Training.” Video, 2011. <https://www.faa.gov/tv/?mediaid=400>.
- . *Memorandum of Understanding between the National Air Traffic Controllers Association and the Federal Aviation Administration*. Washington, DC: Federal Aviation Administration, 2009. https://www.faa.gov/pilots/safety/media/Fatigue_MOA.pdf.
- . “Mission.” 2016. <http://www.faa.gov/about/mission/>.
- . *National Airspace System Overview*. Washington, DC: Federal Aviation Administration, 2016. https://www.faa.gov/air_traffic/nas/nynjphl_redesign/documentation/feis/media/Appendix_A-National_Airspace_System_Overview.pdf.
- . *Pilot’s Handbook of Aeronautical Knowledge 2016*. Newcastle, WA: Aviation Supplies & Academics, 2016.
- . *Risk Management Handbook*. Washington, DC: U.S. Department of Transportation, 2009. https://www.faa.gov/regulations_policies/handbooks_manuals/aviation/media/faa-h-8083-2.pdf.
- . *The Economic Impact of Civil Aviation on the U.S. Economy*. Washington, DC: U.S. Department of Transportation, 2014. https://www.faa.gov/air_traffic/publications/media/2014-economic-impact-report.pdf.
- . *The First U.S. Federal Pilot License*. Washington, DC: Federal Aviation Administration, n.d. Accessed September 9, 2016. https://www.faa.gov/about/history/milestones/media/first_pilots_license.pdf.
- . “U.S. Civil Airmen Statistics.” Last modified April 25, 2016. https://www.faa.gov/data_research/aviation_data_statistics/civil_airmen_statistics/.
- . *VFR Weather Minimums*. Washington, DC: Federal Aviation Administration, n.d. Accessed December 7, 2016. <https://www.faa.gov/files/gslac/courses/content/25/185/VFR%20Weather%20Minimums.pdf>.
- Feiveson, Harold. *On the Global Nuclear Future*. Cambridge, MA: MIT Press for the American Academy of Arts and Sciences, 2009.
- Fox, Michael. “How Real-Time Crime Center Technologies Are Force Multipliers.” PoliceOne, April 14, 2014. <https://www.policeone.com/police-products/police-technology/articles/7083433-How-real-time-crime-center-technologies-are-force-multipliers/>.

- Fraternal Order of Police Chicago Lodge 7. *Agreement between the Fraternal Order of Police Chicago Lodge No. 7 and the City of Chicago*. Chicago: Fraternal Order of Police Chicago Lodge 7, 2007. http://www.chicagofop.org/contract/contract_07-12.pdf.
- Frost, Von N. E., K. J. Marsh, and L. P. Pook. *Metal Fatigue*. Oxford [England]: Clarendon Press, 1974.
- Glaser, Barney G., and Anselm L. Strauss. *The Discovery of Grounded Theory*. Chicago: Aldine Pub. Co., 1967.
- Groeger, John A. *Youthfulness, Inexperience, and Sleep Loss: The Problems Young Drivers Face and Those They Pose for Us*. Guildford, UK: Injury Prevention, 2006. <http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.551.6334&rep=rep1&type=pdf>.
- Hancock, Peter A., and H. C. Neil Ganey. "From the Inverted-U to the Extended-U: The Evolution of a Law of Psychology." *Journal of Human Performance in Extreme Environments* 7, no. 1 (2003): 4–11. doi: 10.7771/2327-2937.1023.
- Harville, Donald, Richard Harrison, and Chaiken Scott. *The Fatigue Equivalent of Job Experience and Performance in Sustained Operations*. Fort Belvoir, VA: Defense Technical Information Center, 2006.
- Heitmann, Anneke, Meghan Slipka, Greg Jones, E. Hamilton, David Weisburd, and Karen L. Amendola. *The Shift Length Experiment: What We Know About 8-, 10-, and 12-Hour Shifts in Policing*. Washington, DC: Police Foundation, 2011. https://www.policefoundation.org/wp-content/uploads/2015/06/ShiftLengthExperiment_0.pdf.
- Hockey, Robert, Anthony W. K. Gaillard, and Oleksandr Burov. *Operator Functional State*. Amsterdam: IOS Press, 2003.
- Homeland Security. "About Fusion Centers." 2016. <https://www.dhs.gov/state-and-major-urban-area-fusion-centers>.
- Hopstaken, Jesper F., Dimitri van der Linden, Arnold B. Bakker, and Michiel A. J. Kompier. "A Multifaceted Investigation of the Link between Mental Fatigue and Task Disengagement." *Psychophysiol* 52, no. 3 (2014): 305–315. doi: 10.1111/psyp.12339.
- Houston Police Department. *Annual Report*. Houston: Houston Police Department, 2010.
- Idaho National Labs—United States Department of Energy. "Nuclear Pioneers: EBR-1." 2003. <http://www4vip.inl.gov/ebr/>.

- Indiana Intelligence Fusion Center. "Mission Statement." Accessed December 7, 2016. <http://www.in.gov/iifc/2336.htm>.
- International Association of Chiefs of Police. *Criminal Intelligence Sharing Report*. Alexandria, VA: International Association of Chiefs of Police, 2002. <http://ric-zai-inc.com/Publications/cops-w0418-pub.pdf>.
- International Atomic Energy Agency. *Control Room Systems Design for Nuclear Power Plants*. Vienna, Austria: International Atomic Energy Agency, 1995. http://www.iaea.org/inis/collection/NCLCollectionStore/_Public/27/002/27002051.pdf.
- Jaludi, Abdul. *Command Center Handbook: Proactive IT Monitoring*. North Charleston, SC: Create Space, 2014.
- Kenney, Dennis Jay, and Bryan Vila. *Tired Cops: The Prevalence and Potential Consequences of Police Fatigue*. Washington, DC: National Institute of Justice, 2002. <https://www.ncjrs.gov/pdffiles1/jr000248d.pdf>.
- Khawla, Abu. "Understanding Homegrown Terrorism." *American Thinker*, December 12, 2010. http://www.americanthinker.com/articles/2010/12/understanding_homegrown_terror.html.
- Killgore, William D. S., Ellen T. Kahn-Greene, Erica L. Lipizzi, Rachel A. Newman, Gary H. Kamimori, and Thomas J. Balkin. "Sleep Deprivation Reduces Perceived Emotional Intelligence and Constructive Thinking Skills." *Sleep Medicine* 9, no. 5 (2008): 517–526. doi: 10.1016/j.sleep.2007.07.003.
- Kilner, Andrew, and Nuno Cebola. *When Are You Too Tired to Be Safe? Exploring the Construction of a Fatigue Index in the ATM*. Lisbon: Lisbon University Institute, 2009. [https://eurocontrol.int/eec/gallery/content/public/document/other/conference/2009/safety_r_and_d_Munich/day_2/Andy-Kilner-\(EUROCONTROL\)-Paper.pdf](https://eurocontrol.int/eec/gallery/content/public/document/other/conference/2009/safety_r_and_d_Munich/day_2/Andy-Kilner-(EUROCONTROL)-Paper.pdf).
- Knipling, R. R., and J. S. Wang. *Crashes and Fatalities Related to Driver Drowsiness/Fatigue: Research Note*. Washington, DC: National Highway Traffic Safety Administration, 1994.
- LeDuc, P. A., J. A. Caldwell, and P. S. Ruyak. *The Effects of Exercise versus Napping on Alertness and Mood in Sleep-Deprived Aviators*. Fort Rucker, AL: U.S. Aeromedical Research Laboratory, 2000. <http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.459.2378&rep=rep1&type=pdf>.
- Lindbergh, Charles A. *The Spirit of St. Louis*. New York: Scribner, 1953.
- Liskowsky, David R. *Biological Rhythms: Implications for the Worker*. Washington, DC: U.S. Government Printing Office, 1991. <https://www.princeton.edu/~ota/disk1/1991/9108/9108.PDF>.

- Mahaffey, James A. *Atomic Accidents: A History of Nuclear Meltdowns and Disasters: From the Ozark Mountains to Fukushima*. New York: Open Road Media, 2012.
- Marder, Jenny. "Nuclear Reactors And Nuclear Bombs: What Defines The Differences?." Blog, *PBS Newshour*, 2011. <http://www.pbs.org/newshour/run-down/what-is-the-difference-between-the-nuclear-material-in-a-bomb-versus-a-reactor/>.
- Matthews, Gerald. *Levels of Transaction: A Cognitive Science Framework for Operator Stress*. Dundee, Scotland: ResearchGate, 2001. https://www.researchgate.net/profile/Gerald_Matthews2/publication/284577742_Levels_of_transaction_a_cognitive_sciences_framework_for_operator_stress_in_Stress_Workload_and_Fatigue/links/57c9dd9708ae59825180f5a3.
- McCaul, Michael, and King Peter. *Majority Staff Report on the National Net-Work of Fusion Centers*. Washington, DC: U.S. House of Representatives, 2013. <https://www.archives.gov/isoo/oversight-groups/sltps-pac/staff-report-on-fusion-networks-2013.pdf>.
- MedlinePlus. "Fatigue." Last updated November 1, 2016. <https://medlineplus.gov/ency/article/003088.htm>.
- Memphis Police Association and the City of Memphis. *Agreement between the Memphis Police Association and the City of Memphis, Tennessee*. Memphis, TN: Memphis Police Association and the City of Memphis, 2011. http://www.memphistn.gov/portals/0/pdf_forms/mou/mpa.pdf.
- . "Real Time Crime Center." 2016. <http://www.memphispolice.org/rtcc.asp>.
- Mitler, Merrill M., James C. Miller, Jeffrey J. Lipsitz, James K. Walsh, and C. Dennis Wylie. "The Sleep of Long-Haul Truck Drivers." *New England Journal of Medicine* 337, no. 11 (1997): 755–762. doi: 10.1056/nejm199709113371106.
- National Aeronautics and Space Administration. "1986 Report of the Presidential Commission on the Space Shuttle Challenger Accident." 2016. <http://history.nasa.gov/rogersrep/genindex.htm>.
- National Commission on Terrorist Attacks upon the United States. *The 9/11 Commission Report*. New York: Norton, 2004.
- National Emergency Number Association (NENA). *NENA Call Answering Standard/Model Recommendation*. Alexandria, VA: National Emergency Number Association (NENA) Standard Operating Procedures Committee, 2006. https://cymcdn.com/sites/www.nena.org/resource/resmgr/Standards/NENA_56-005.1_Call_Answering.pdf.

- National Fusion Center Association. *2014–2017 National Strategy for the National Network of Fusion Centers*. Washington, DC: National Fusion Center Association, 2014. <https://nfcausa.org/html/National%20Strategy%20for%20the%20National%20Network%20of%20Fusion%20Centers.pdf>.
- National Institute on Alcohol Abuse and Alcoholism. “Overview of Circadian Rhythms.” 2016. <http://pubs.niaaa.nih.gov/publications/arh25-2/85-93.htm>.
- Nealley, Megan A., and Valerie J. Gawron. “The Effect of Fatigue on Air Traffic Controllers.” *The International Journal of Aviation Psychology* 25, no. 1 (2015): 14–47. doi: 10.1080/10508414.2015.981488.
- Nuclear Energy Institute. *Managing Personnel Fatigue at Nuclear Power Reactor Sites*. (NEI 06-11). Washington, DC: Nuclear Energy Institute, 2011.
- . *Managing Personnel Fatigue at Nuclear Power Reactor Sites*. (NEI 06-11 [Revision 1]). Washington, DC: Nuclear Energy Institute, 2008. <http://www.nrc.gov/docs/ML0903/ML090360158.pdf>.
- NYPD Real Time Crime Center. *Executive Summary*. New York: NYPD Real Time Crime Center, 2007.
- Office of Inspector General. “Component: Transportation Security Administration (TSA).” 2016. https://www.oig.dhs.gov/index.php?option=com_content&view=article&id=22&Itemid=46.
- . *Audit Report: Contract Towers Continue to Provide Cost-Effective and Safe Air Traffic Services, But Improved Oversight of the Program Is Needed*. (FAA Report: AV-2013-009). Washington, DC: Federal Aviation Administration, 2012. <https://www.oig.dot.gov/sites/default/files/FAA%20Federal%20Contract%20Tower%20Program%20Report%5E11-5-12.pdf>.
- Office of Nuclear Regulatory Research. *Fatigue Management for Nuclear Plant Personnel*. Washington, DC: Nuclear Regulatory Commission, 2009. <http://www.nrc.gov/docs/ML0834/ML083450028.pdf>.
- Opguard. “How It Works.” Accessed December 7, 2016. <http://www.guardvant.com/solution/opguard/opguard-how-it-works/>. Guardvant.
- Optalert. “Eagle PORTABLE Drowsiness Detection System.” Accessed December 7, 2016. <http://www.optalert.com/portable-drowsiness-detection>.
- Philadelphia Area Regional Transit Security Working Group. “About DVIC.” Accessed December 7, 2016. <http://www.stayalertnow.com/about-dvic>.

- Phillips, Peter J. "Lone Wolf Terrorism." *Peace Economics, Peace Science and Public Policy* 17, no. 1 (2011): 1–31. https://eprints.usq.edu.au/18630/2/Phillips_PEPS_PP_v17n1_PV.pdf.
- Poli, Joseph A. "The Development and Present Trend of Police Radio Communications." *Journal of Criminal Law and Criminology (1931–1951)* 33, no. 2 (1942): 193. doi: 10.2307/1136443.
- Proctor, Jon. "Lessons from Tragedy over the Grand Canyon." TWA Seniors Club. Updated September 18, 2016. <http://www.twaseniorsclub.org/memories/contrails/tragedygrandcanyonTW-UA.html>.
- Reyes, Emily Alpert, and Doug Smith. "Most L.A. City Employees Don't Live in L.A., Times Analysis Finds." *Los Angeles Times*, June 17, 2014. <http://www.latimes.com/local/la-me-out-of-town-20140608-story.html>.
- Richardson, Courtney, Marion E. Bowman, and Kimberley L. Thachuk. *Homegrown Terrorism: The Threat Within*. Washington, DC: National Defense University, 2008. <http://www.dtic.mil/cgi-bin/GetTRDoc?AD=ada482139>.
- Scottish Engineering Hall of Fame. "William John Macquorn Rankine (1820–1872), Engineer, Polymath, Educator and Researcher. Pioneer of Thermodynamics." Accessed December 7, 2016. <http://www.engineeringhalloffame.org/profile-rankine.html>.
- Scovel, Calvin L. III. *Statement before Congress: Update on the Safety and Cost Aspects of the Federal Aviation Administration's Contract Tower Program*. Washington, DC: Department of Transportation, 2012. <https://www.oig.dot.gov/sites/default/files/Contract%20Tower%20Hearing%20Statement%5E7-18-12.pdf>.
- Shappel, Scott A., and Douglas A. Wiegmann. *The Human Factors Analysis and Classification System—HFACS*. Washington, DC: U.S. Federal Aviation Administration, Office of Aviation Medicine, 2000.
- Sovacool, Benjamin K. "The Costs of Failure: A Preliminary Assessment of Major Energy Accidents, 1907–2007." *Energy Policy* 36, no. 5 (2008): 1802–1820. doi: 10.1016/j.enpol.2008.01.040.
- Staal, Mark. *Stress, Cognition, and Human Performance: A Literature Review and Conceptual Framework*. Moffett Field, CA: National Aeronautics and Space Administration, Ames Research Center, 2004. https://human-factors.arc.nasa.gov/flightcognition/Publications/IH_054_Staal.pdf.
- Stacy, Susan. *Proving the Principle*. Idaho Falls, ID: United States Department of Energy, 2000. http://www4vip.inl.gov/publications/d/proving-the-principle/chapter_06.pdf.

- Stanton, Neville A. *Human Factors in Nuclear Safety*. Boca Raton, FL: CRC Press, 1996.
- Stello, Victor Jr. *Order Suspending Nuclear Power Operation—Peach Bottom Power Plant*. Washington, DC: United Nuclear Regulatory Commission, 1987. <http://www.nrc.gov/docs/ML0113/ML011370002.pdf>.
- Three Mile Island Alert. “A Corporate History of Three Mile Island.” Accessed December 7, 2016. <http://www.tmia.com/corp.historyTMI>.
- Tong, Shao Chuen, Aung Soe Tin, Darren M. H. Tan, and Jeremy F. Y. Lim. “Health-Related Quality of Life of Junior Doctors.” *Annals Academy of Medicine—Singapore* 41, no. 10 (2016): 444–450. <http://www.annals.edu.sg/pdf/41VolNo10Oct2012/V41N10p444.pdf>.
- Treat, J. R., N. S. Tumbas, S. T. McDonald, D. Shinar, R. D. Hume, R. E. Mayer, R. L. Stansifer, and N. J. Castellan. *Tri-level Study of the Causes of Traffic Accidents*. (Publication no. DOT-HS- 034-3-535-77 (TAC)). Bloomington, IN: Indiana University, 1979.
- Turek, Fred W., Joseph S. Takahashi, and Martha Hotz Vitaterna. “Overview of Circadian Rhythms.” *Alcohol Research and Health* 25, no. 2 (2001): 85–93. https://www.researchgate.net/profile/Joseph_Takahashi/publication/11764172_Overview_of_circadian_rhythms/links/0c960525dc638d9dfe000000.pdf.
- U.S. Atomic Energy Commission. *Atomic Energy Act of 1946*. Washington, DC: U.S. Department of Energy, 1946. <https://www.osti.gov/atomicenergyact.pdf>.
- U.S. Department of Justice and U.S. Department of Homeland Security. *Fusion Center Guidelines*. Washington, DC: U.S. Department of Justice and U.S. Department of Homeland Security, 2006. http://it.ojp.gov/documents/d/fusion_center_guidelines.pdf.
- U.S. Department of Transportation. *Operations Specification—A319, Fatigue Education and Awareness Training (FEAT) Program*. Washington, DC: Federal Aviation Administration, 2016. http://www.faa.gov/documentLibrary/media/Notice/N_8900.347.pdf.
- United States Department of Justice. *National Criminal Intelligence Sharing Plan*. Washington, DC: United States Department of Justice, 2003. https://it.ojp.gov/documents/ncisp/National_Criminal_Intelligence_Sharing_Plan.pdf.
- United States Nuclear Regulatory Commission. “10 CFR 26.211 Fatigue Assessments.” Last reviewed/updated December 2, 2015. <http://www.nrc.gov/reading-rm/doc-collections/cfr/part026/part026-0211.html>.
- . “10 CFR 26.29 Training.” Last reviewed/updated December 2, 2015. <http://www.nrc.gov/reading-rm/doc-collections/cfr/part026/part026-0029.html>.

- . “10 CFR 26.405 Drug and Alcohol Testing.” Last reviewed/updated December 2, 2015. <http://www.nrc.gov/reading-rm/doc-collections/cfr/part026/part026-0405.html>.
- . “10 CFR Part 26—Fitness for Duty Programs.” Last reviewed/updated November 8, 2016. <http://www.nrc.gov/reading-rm/doc-collections/cfr/part026/full-text.html#part026-0075>.
- . “About NRC.” Accessed December 7, 2016. <http://www.nrc.gov/about-nrc.html>.
- . “Backgrounder on Oversight of Nuclear Power Plants.” Last reviewed/updated May 18, 2016. <http://www.nrc.gov/reading-rm/doc-collections/fact-sheets/oversight.html>.
- . *Frequently Asked Questions about Fatigue Management Program*. Washington, DC: Nuclear Regulatory Commission, 2016. <http://www.nrc.gov/docs/ML0925/ML092530677.pdf>.
- . “Glossary—Outage (Forced).” Last reviewed/updated June 21, 2016. <http://www.nrc.gov/reading-rm/basic-ref/glossary/outage-forced.html>.
- . “Glossary—Outage (Scheduled).” Last reviewed/updated, June 21, 2016. <http://www.nrc.gov/reading-rm/basic-ref/glossary/outage-scheduled.html>.
- . “History of The NRC’s Fitness-for-Duty Requirements.” Last reviewed/updated August 12, 2013. <http://www.nrc.gov/reactors/operating/ops-experience/fitness-for-duty-programs/history.html>.
- . *NRC Mission Statement*. Washington, DC: United States Nuclear Regulatory Commission, 2007. <http://pbadupws.nrc.gov/docs/ML0704/ML070460435.pdf>.
- . *Nuclear Reactor*. Washington, DC: Nuclear Regulatory Commission, 2014. <http://www.nrc.gov/docs/ML1525/ML15254A456.pdf>.
- . *Regulatory Guide 5.73—Fatigue Management for Nuclear Personnel*. Washington, DC: United States Nuclear Regulatory Commission, 2009. <http://www.nrc.gov/docs/ML0834/ML083450028.pdf>.
- . “Safety Culture.” Last reviewed/updated March 3, 2016. <http://www.nrc.gov/about-nrc/safety-culture.html>.
- . *Self-Declarations of Fitness for Duty*. Washington, DC: United States Nuclear Regulatory Commission, 2002. <http://www.nrc.gov/reading-rm/doc-collections/gen-comm/reg-issues/2002/ri02007.pdf>.

- . *Three Mile Island Accident*. Washington, DC: United States Nuclear Regulatory Commission, 2013. <http://www.nrc.gov/reading-rm/doc-collections/fact-sheets/3-mile-isle.pdf>.
- Van Erp, Jan. *Safety Culture and the Accident at Three Mile Island*. Argonne, IL: Argonne National Laboratory, 2002. http://www.iaea.org/inis/collection/NCLCollectionStore/_Public/34/007/34007188.pdf.
- Violanti John. *Shifts, Extended Work Hours, and Fatigue: An Assessment of Health and Personal Risks for Police Officers*. Washington, DC: National Institute of Justice, 2016. <https://www.ncjrs.gov/pdffiles1/nij/grants/237964.pdf>.
- Waggoner, Lauren B. “Police Officer Fatigue: The Effects of Consecutive Night Shift Work on Police Officer Performance.” PhD diss., Washington State University, 2012.
- Whitmore, Jeff, Scott Chaiken, Joseph Fischer, Richard Harrison, and Donald Harville. *Sleep Loss and Complex Team Performance*. Ft. Belvoir: Defense Technical Information Center, 2008.
- Wilson, Jill, and Mark Hutchins. *The Federal Aviation Administration’s Approach for Determining Future Air Traffic Controller Staffing Needs*. (Special Report No. 314). Washington, DC: National Academies Press, 2015. <http://onlinepubs.trb.org/onlinepubs/sr/sr314.pdf>.
- Yerkes, Robert M., and John D. Dodson. “The Relation of Strength of Stimulus to Rapidity of Habit-Formation.” *Journal of Comparative Neurology and Psychology* 18, no. 5 (1908): 459–482. doi: 10.1002/cne.920180503.
- Zwyghuizen-Doorenbos, Ardith, Timothy A. Roehrs, Lauren Lipschutz, Victoria Timms, and Thomas Roth. “Effects of Caffeine on Alertness.” *Psychopharmacology* 100, no. 1 (1990): 36–39. doi: 10.1007/bf02245786.

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