

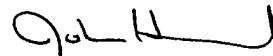
REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188	
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.				
1. AGENCY USE ONLY (Leave blank)		2. REPORT DATE 10 Jun 1998		3. REPORT TYPE AND DATES COVERED
4. TITLE AND SUBTITLE INCIDENT OF UNITED STATES AIR FORCE AIRCREW FATIGUE IN THE OPERATIONAL SETTING			5. FUNDING NUMBERS	
6. AUTHOR(S) Karl E. Lee				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) THE UNIVERSITY OF TEXAS HEALTH SCIENCE CENTER AT HOUSTON SCHOOL OF PUBLIC HEALTH			8. PERFORMING ORGANIZATION REPORT NUMBER  98-025	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) THE DEPARTMENT OF THE AIR FORCE AFIT/CIA, BLDG 125 2950 P STREET WPAFB OH 45433			10. SPONSORING/MONITORING AGENCY REPORT NUMBER	
11. SUPPLEMENTARY NOTES				
12a. DISTRIBUTION AVAILABILITY STATEMENT Unlimited distribution In Accordance With AFI 35-205/AFIT Sup 1			12b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words)				
19980618 040				
14. SUBJECT TERMS			15. NUMBER OF PAGES 54	
			16. PRICE CODE	
17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT	

INCIDENCE OF UNITED STATES AIR FORCE AIRCREW FATIGUE IN THE  
OPERATIONAL SETTING

By

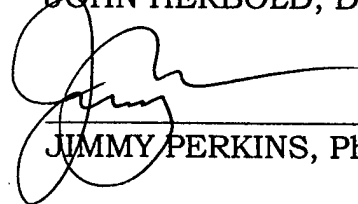
KARL E. LEE, BA, DO

APPROVED:



---

JOHN HERBOLD, DVM, PhD



---

JIMMY PERKINS, PhD

INCIDENCE OF UNITED STATES AIR FORCE AIRCREW FATIGUE IN THE  
OPERATIONAL SETTING

By

KARL E. LEE, BA, DO

THESIS

Presented to the Faculty of the University of Texas

Health Science Center at Houston

School of Public Health

in Partial Fulfillment

of the Requirements

for the Degree of

MASTER OF PUBLIC HEALTH

THE UNIVERSITY OF TEXAS HEALTH SCIENCE CENTER AT HOUSTON  
SCHOOL OF PUBLIC HEALTH  
Houston, Texas  
May 1998

## ACKNOWLEDGEMENTS

I would like to respectfully acknowledge the patient assistance of my masters thesis committee, and my advisors Dr John Herbold and Dr Jimmy Perkins. I would like to thank Dr Jonathan French, who graciously facilitated my efforts to gain Air Force approval to study first-hand, aircrew fatigue in the operational setting. A hearty thank you goes to Major Rene Bergeron, for his friendly assistance in orienting me to the C-5 community as well as his help in every aspect of data gathering. A special mention should be made to Ann Dougherty and Kathleen Cook, members of the Committee for the Protection of Human Subjects, for expediting the approval for my research activities. Saving the most important for last, I wish to thank my wife Devon, and my children Kristina, Kathryn and Nathan for their continued love and support.

Thesis submitted to MPH committee 20 April 1998

# INCIDENCE OF UNITED STATES AIR FORCE AIRCREW FATIGUE IN THE OPERATIONAL SETTING

Karl E. Lee, BA, DO, MPH  
The University of Texas  
Health Science Center at Houston  
School of Public Health, 1998

Supervision Professor: John Herbold

Though subjective fatigue measures have been utilized in assessing aircrew fatigue, no studies to date have attempted to establish its overall incidence in the USAF flying community. The purpose of this study was to investigate the incidence of subjective fatigue in the USAF operational environment, looking specifically at those pilots and flight engineers that regularly fly long transport missions. The study group included all pilots and flight engineers belonging to the United States Air Force Reserve's 68<sup>TH</sup> Airlift Squadron stationed at Kelly AFB, TX. This squadron has approximately 65 pilots and 70 flight engineers and utilizes the C-5 Galaxy transport aircraft exclusively. Pre and postmission questionnaires were completed prior to and at mission completion respectively. Throughout the mission, the study subjects completed a mission log, which tracked type of activity, serial fatigue rating, and place of sleep. Subjective fatigue was rated starting at mission onset, every four hours throughout the mission

and at mission completion, that is, at time of engine shut down. Fatigue was measured using the School of Aerospace Medicine (SAM) seven point fatigue scale. Despite the endorsement of the wing commander, full support of the wing safety officer, two separate briefings to the squadron at monthly safety briefings, and placement of questionnaire packets in over 135 individual's vertical files (V-files or "mail boxes), only six questionnaire packets were returned. Despite the lack of response, this study does serve as a pilot study, which together with lessons learned may prove useful in future studies of USAF aircrew fatigue in the operational setting.

## TABLE OF CONTENTS

	Page
List of Tables.....	vii
List of Figures .....	viii
List of Appendices .....	ix
Introduction.....	1
Basic Science Background .....	2
Sleep .....	2
Circadian Rhythm .....	3
Literature Review .....	6
Fatigue in the Civilian Workplace .....	6
Impact of Fatigue in the Civilian Workplace.....	7
The United States' Military Aviation Experience 1975 to 1995.....	9
The USAF Experience .....	10
Human Error, Human Factor, Fatigue and the Operational Environment .....	11
Aircrew Fatigue in the Operational Environment.....	12
Aircrew Fatigue: USAF Policy and Countermeasures .....	16
Purpose.....	17
Methods and Materials.....	18
Results.....	21
Discussion .....	22
Conclusion.....	27
Appendices .....	28
Bibliography.....	53
Vita .....	55

## LIST OF TABLES

Table 1: Fatigue Countermeasures Listed by C-5 Aircrew..... Appendix 1

Table 2: Contributing Factors Leading to Aircrew Fatigue ..... Appendix 1

Table 3: Fatigue Countermeasures Utilized by C-5 Aircrew ..... Appendix 1



## LIST OF FIGURES

Figure 1: Episodes of Subjective Fatigue in C-5 Aircrew ..... Appendix 2

Figure 2: Adverse Affect of Fatigue on Selected Human Factors. Appendix 2

## LIST OF APPENDICES

	Page
Appendix 1: Tables .....	28
Appendix 2: Figures .....	29
Appendix 3: Pre-Mission Questionnaire .....	30
Appendix 4: Post-Mission Questionnaire .....	31
Appendix 5: Mission Log .....	32
Appendix 6: Squadron Briefing Slides .....	33
Appendix 7: Cover Letter .....	35
Appendix 8: Letter of Information .....	36
Appendix 9: 433 <sup>rd</sup> Airlift Wing Approval Letter .....	37
Appendix 10: Advisory Committee for Human Experimentation Request .....	38
Appendix 11: Committee for the Protection of Human Subjects Request .....	43

## INTRODUCTION

Until the dawn of the industrial age the human workforce was primarily diurnal, working from dawn until dusk and resting from dusk until dawn. This "natural" work schedule was well suited to the geophysical world in which virtually all creatures (eukaryotes and above) evolved an internal timing system that enabled them to best adapt to its natural rhythmic schedule of day and night. In mammals, this internal timing system consists of a group of neural structures in the central nervous system mediated by neurochemicals. It is collectively termed the circadian timing system (14).

Within the past century, the advent of the electric light (permitting work at night) as well as aircraft capable of rapidly traversing time zones, gave rise to a new health concern: fatigue due to circadian desynchrony (22). The passing of the twentieth century has indeed seen our technological society evolve into a full-blown, twenty-four hour operation. The United States' Armed Forces, without a doubt, have not been excluded from this evolutionary trend.

Currently in the United States, at least twenty one million people are shift workers. This represents about twenty percent of the US workforce with one fourth of employed men and one sixth of women working shifts (16). Of this group, 40% to 80% experience disturbed sleep, with permanent night and rotating shift workers averaging 6 and 5.5 hours of sleep per night respectively (16). Their sleep disruption is a result of a mismatch between an imposed external sleep/wake schedule and the dictates of their internal circadian timing system (15). The principle physiological disruption experienced by these individuals occurs primarily in two areas, sleep and circadian rhythm.

Similar mismatches and disruptions occur on a regular basis for United States Air Force (USAF) transport aircrew responsible for moving supplies and personnel to virtually any part of the world at any time of the day or night in support of the United States' national security interest. The resultant fatigue and performance decrement experienced by these aircrew have been studied in both operational and simulated environments (5,8,13). However, no studies to date have specifically addressed the question of just what the incidence of aircrew fatigue is in the USAF operational environment. This study is designed to answer that question in order to quantify the baseline extent of the problem (i.e. aircrew fatigue) and thus lay the foundation for further studies in fatigue related performance decrements and effectiveness of specific countermeasures.

## **BASIC SCIENCE BACKGROUND**

### **Sleep**

Sleep, in simple terms, is a reversible behavioral state of perceptual disengagement from, and unresponsiveness to the environment (21). Although historically viewed as a time during which the human organism is turned off, research over the past 40 years has shown sleep to be a complex, active physiological state that is essential for human survival (9). Studies have shown that sleep occurs in two different states: non-rapid eye movement (NREM) and rapid eye movement (REM).

NREM sleep is classically divided into four stages that are defined primarily by electroencephalographic EEG patterns. These four stages are associated with decreased mental and increased motor activity. They roughly parallel a 'depth of sleep' continuum, with arousal thresholds being lowest in stage 1 and highest in

stage 4. In short, NREM can be thought of as a relatively inactive (though still regulating) brain in a movable body. In contrast, REM sleep is defined by EEG activation, muscle atonia, and episodic bursts of rapid eye movement. In short, the picture is one of a highly activated brain in a paralyzed body (21).

Normal sleep is entered through the NREM state, which is followed by the REM state. This NREM and REM alternation (80% NREM – 20 % REM) repeats 4-6 times throughout the sleep cycle with a periodicity of about 90 minutes. NREM sleep predominates in the 1st third (linked to initiation of sleep) and REM in the last third (linked to the circadian timing system and coincident with the trough in core body temperature) of the sleep cycle (21). The timing, balance and duration of each component of sleep are critical in maintaining homeostasis.

### **Circadian Rhythm**

In all mammals, the circadian (circa = about, dies = day) timing system (CTS) is a complex group of structures, pathways, hormones and neurotransmitters that mediates (over a 24 hour period) the regulation of hormonal output, body core temperature, rest, activity, sleep, wakefulness, as well as motor and cognitive function (14). Its role is to provide temporal organization of physiologic processes and behavior to promote effective adaptation to the environment. The end result (given a normal 24 hour cycle and sleep at night) is a nadir in overall physiologic function, performance capabilities and core body temperature from 3 to 5 A.M. These findings are concurrent with the time of maximal reported sleepiness (9). This is a time for sleep, that all-important physiologic function during which the body and brain revitalize. As morning comes, the wake phase of the sleep/wake continuum prepares the body for the

rigors of the day with increased physiologic functioning, and body temperature. It is the nadir in core body temperature that is used to designate the phase of the circadian rhythm. Its reliability, robustness, and ease of measure make it extremely valuable in monitoring the phase of the circadian cycle.

Separated from external environmental cues (in a controlled test environment), the CTS reverts to its own endogenous free-running rhythm cycle with a duration very near 24 hours (14). However, to provide an effective time keeping role in the real world, the CTS's endogenous oscillations must be stabilized to the external environment. This stabilization process is referred to as entrainment, and the environmental cues are called Zeitgebers (light giver) (1).

Light (in intensity approaching that of the sun) is the principal Zeitgeber for the CTS – it establishes the period and phase of the circadian pacemaker (1). Its effect, however, is dependent on the time of exposure in relation to the phase of the endogenous circadian cycle. Given that day is from 0600 to 1800 and night 1800 to 0600; light administered from 0800 to 1600 has no effect on CTS phase activity, from 1600 to 2200 will phase delay CTS activity, and from 2400 to 0800 will phase advance CTS activity. In other words the CTS “sees” light from 1600 to 2200 as lengthening the day and attempts to reset its activity to later in the day i.e. a phase delay. Conversely, the CTS “sees” light from 2400 to 0800 as advancing the onset of the day and attempts to reset its activity to earlier in the day i.e. a phase advance. This relationship between time of light exposure and response of the CTS is described in a “phase response curve” (PRC) (1).

The pacemaker of the human CTS lies in the suprachiasmatic nuclei (SCN) located in the hypothalamus, in a region adjacent to the optic chiasm. The SCN

has 2 subdivisions: a core, that receives predominately visual input, and a shell that receives input from other various sources. External light information is relayed to the SCN via the retinohypothalamic tract – the photoentrainment pathway. Although light is the primary Zeitgeber, there are other factors that can affect circadian phase. The intergeniculate leaflet (IGL), off the lateral geniculate complex, has projections back to the SCN. It is postulated that this pathway may integrate photic and nonphotic (e.g. locomotor activity) entrainment information (sun light type PRC) to the SCN (1). The SCN also has abundant melatonin receptors that may serve as part of a SCN pineal gland feedback loop (14). It is well known that melatonin has a known PRC with characteristics opposite that of sun light. Other hormones appear to play an important role, though not essential, in regulating circadian rhythms. Their action may involve modulation of coupling relationships between oscillators or between oscillators and other overtly expressed rhythms (14). Factors such as food availability, ambient temperature, forced activity, and social cues may also serve to entrain biological rhythms (14).

The SCN's major efferent projections are to the hypothalamus with lesser ones to the basal forebrain and the middle thalamus. The SCN neuronal firing is diurnal with GABA as the neurotransmitter – thus signals sent are inhibitory (1). These circadian signals are transmitted to the anterior pituitary, hypothalamic and brainstem reticular regions that are involved with autonomic regulation, control of metabolism, body temperature, and temporal organization of sleep/wake cycles (1). The Pineal gland receives SCN input via postganglionic neurons arising from the superior cervical ganglion. This results in melatonin levels increasing dramatically after dusk, peaking in the middle of the dark period, and decreasing around dawn.

This endogenous fatiguing agent is a circadian phase modulator, creating a phase response curve opposite that of sun light (2). Some pharmaceuticals also affect the phase of the endogenous circadian rhythm.

## **LITERATURE REVIEW**

### **Fatigue in the Civilian Workplace**

Shift work can be a risk factor for human health and well being (11). The 21 million US shift workers are exposed to major disruptions in their physiology, social activities and family lives (12). The principle physiological disruption occurs primarily in two areas: sleep and circadian rhythm. Circadian desynchrony can develop as a result of shiftwork, transition across time zones or other sleep disorders. Sleep loss can occur acutely or sequentially over time, with a resultant accumulated sleep debt. Cumulative sleep loss and circadian disruption can lead to decreased waking alertness, impaired performance, and worsened mood. This constellation of subjective symptoms is often characterized as fatigue (12). Other signs and symptoms of fatigue include; forgetfulness, poor decision making, slowed reaction time, reduced vigilance, poor communication, apathy, moodiness, and a tendency to become fixated and nod-off. Sleepiness is difficult at times to distinguish from fatigue. Some authors make a distinction between subjective sleepiness (an introspective perception that can be transiently masked by physical activity, stress, excitement etc.) and physiologic sleepiness (an innate drive to meet the need for sleep). The discrepancy between subjective and physiologic sleepiness can be operationally important. Due to transient masking factors, an individual may under-report their actual level of sleepiness while actually carrying a significant sleep debt with a high degree of physiological sleepiness. Exposed to an



environment stripped of the masking factors may experience sudden onset uncontrollable sleep (9). Although many factors are associated with fatigue (stress, workload etc.), the 2 principle physiologic sources are sleep loss and circadian disruption (12).

### **Impact of Fatigue in the Civilian Workplace**

Human error is often claimed as an important factor in work related accidents. Though its causes are multi-factorial, human error can certainly be related to diminished levels of performance and vigilance. Performance efficiency appears to parallel the circadian rhythm of body temperature. Desynchronization of circadian rhythm cycles in association with fatigue and sleep deficit significantly decreases work efficiency at night, and the worker becomes more vulnerable to errors and accidents. Vigilance can also be compromised by similar conditions and exacerbated further by tasks requiring prolonged physical and mental effort (11).

The Association of Professional Sleep Societies Committee on Catastrophes, Sleep and Public Policy was asked to form in 1986 and investigate the role of human sleep and circadian rhythms in the occurrence of medical and human error catastrophes (24). They noted the presence of increased sleep tendency and diminished performance during early morning hours (2 to 7 a.m.) as well as mid-afternoon (2 to 5 p.m.) – effects independent of sleep (24). Superimposed on these vulnerable times are the effects of fatigue secondary to sleep loss and/or circadian desynchrony.

The committee's findings were fairly consistent: motor vehicle accidents due to "falling asleep at the wheel" show bimodal peaks between 1 and 4 a.m. and 1 and 4 p.m.; single vehicle truck accidents peak between 1 and 7 a.m.; trucking

accidents involving hazardous materials peaked between 6 and 9 a.m.; Federal Railways reported a bimodal peak of automatically induced braking accidents between 3 and 6 a.m. and 1 and 3 p.m.; and finally, Swedish gas works reported a bimodal peak in meter reading errors between 3 and 6 a.m. and 1 and 3 p.m. It is interesting that human mortality in general has bimodal peaks between 4 and 6 a.m. with a smaller peak between 2 and 4 p.m. and myocardial infarctions peak between 6 and 10 a.m. (24).

Many well known disasters can be traced in part to human error committed at during the high risk early morning hours. Between 4 and 6 a.m., March 28 1979, shift workers at The Three Mile Island nuclear power plant in Pennsylvania, failed to recognize loss of core coolant water caused by a stuck valve. This resulted in the most serious commercial power plant incident in the history of the United States. Two other nuclear power plant incidents, occurring at 1:35 a.m. and 4:14 a.m. in Oak Harbor, Ohio and Sacramento, California respectively, were exacerbated by human errors. Most sobering is the fact that the nuclear power plant catastrophe at Chernobyl is officially acknowledged to have begun at 1:23 a.m. as the result of human error. Finally, the Presidential Commission on the Space Shuttle Challenger Accident did note the contribution of human error and poor judgement related to sleep loss and shift work during early morning hours. The report cited that the effect on managers of irregular working hours and insufficient sleep "may have contributed significantly to the atmosphere of the teleconference" held at Marshal Space Flight Center with Morton-Thiokol the night prior to launch. Certain key managers had obtained less than 2 hours of sleep and had been on duty since 1:00 a.m. that morning (24).

Most transportation system accidents are due to human error. In fact, depending on the mode of transportation, human error is responsible for 65 – 90% of all such accidents (23). The National Safety Council (Accident Facts, 1987 edition) reported 47,900 deaths resulting from highway accidents in 1986. They estimated \$57.8 billion in lost wages, medical expenses, insurance costs, and property damage. The Federal Railroad Administration reported \$167.5 million in reportable damages in their industry. In a study of jet transport accidents, Boeing identified flight crew error as responsible for 65% of all such accidents since the dawn of the jet age (23). A single major accident can cost an airline an estimated \$500 million in total costs (23).

#### **The United States' Military Aviation Experience 1975 to 1995**

The Department of Defense (DoD) is very concerned about aviation safety. One measure used to track safety by the DoD is mishap rate (Class A flight mishaps per 100,000 hours flying time). A Class A mishap is defined as one involving a DoD aircraft with the intent to fly, that results in damages totaling \$1 million or more, a destroyed aircraft, a fatality, or a permanent disability (17). DoD requires all Class A mishaps to be formally investigated in order to establish cause and promote safety through prevention.

From 1975 through 1995, DoD recorded a total of 3,828 Class A mishaps, resulting in 3,483 aircraft destroyed and 3,810 fatalities. These cumulative figures are impressive. However, when comparing yearly data, it becomes clear that over the past 20 years DoD aviation safety has improved dramatically. From 1975 through 1995 yearly Class A mishaps decreased from 309 to 76, yearly fatalities decreased from 285 to 85, and annual mishap rate decreased from 4.3 to 1.5. The

associated costs of Class A mishaps are staggering. From 1990 to 1995, the annual dollar value loss due to Class A mishaps ranged from a low of \$1.2 billion in fiscal year 1994 to a high of \$1.6 billion in fiscal year 1993 (17)

Since the crash of Orville Wright's aircraft in 1909, and the subsequent death of Tom Selfridge, aircraft mishap investigators have tried to systematically determine causal factors and implement changes to prevent future occurrences (18). Causal factors have been categorized into those due to materials (system or mechanical failure), the environment, and human error. The above noted record of improvement has been due in large part to the services' commitment to reducing aviation mishaps. Many steps have been taken to include; tracking of mishap investigation recommendations, disseminating safety information in manuals, newsletters, videos, messages, briefings and setting aside specific "down-days" for review of safety issues. As a result, great strides have been made in decreasing mishaps due to material factors, but little gain has been made in reducing the percentage of mishaps due to human error. Human error continues to be the leading cause of aircraft mishaps in both the civilian as well as military communities. In DoD, human error contributed to 73 percent of the Class A flight mishaps in fiscal years 1994 and 1995 (19).

### **The USAF Experience**

The United States Air Force flying community is currently composed of 14,457 pilots and 5,482 navigators partitioned out to one of 90 wings still in existence within one of the 17 remaining Numbered Air Forces. They are assigned to any one of 75 continental United States (CONUS) or 20 overseas bases from which they operate on a 24-hour readiness schedule (19). The U.S.A.F. aviation

community has seen, in the 1990's, a reduction in manning and aircraft without corresponding changes in operational tempo (17). This streamlined air force is faced with defending U.S. national interests in support of our global reach, power, and engagement policies. Long range and continuous air operations are thus a common challenge for aircrews.

The U.S.A.F., like the DoD overall, has seen its aviation safety record improve dramatically over the past 20 years. Annual figures from 1975 through 1995 show a decrease in Class A mishaps from 99 to 33, aircraft destroyed from 52 to 29, fatalities from 141 to 53, and mishap rate from 2.8 to 1.5 (17). Although gains have been made in decreasing mishaps due to material causes (system and mechanical failure), human error continues to account for the majority of all mishaps - 71 percent from 1990 to 1995 (17).

#### **Human Error, Human Factor, Fatigue, and the Operational Environment**

The term human factor in aviation is defined in various ways by different authors (18). The most common use of the term denotes the relationship between the aviator (human), the aircraft (machine), and the environment. This term encompasses a complex group interrelated factors to include training, proficiency, currency, experience, judgement, decision making, motivation, physical fitness, physiology, personal stress, nutrition, and fatigue (18). It is a disturbance/imbalance of one or more of these factors in the flight environment that leads to human error - the most common cause of aircraft mishaps. The degree to which each factor contributes to cause will vary from mishap to mishap. In light of what is known with regards to fatigue and performance, it is hard to imagine that the presence of fatigue could not be directly causal or at least

exacerbate human error due to a combination of any of the human factors listed above. Indeed, analyses of confidential reports to the NASA Aviation Safety Reporting System indicated approximately 21 percent of all reported incidents are fatigued related (3).

Mission requirements in the current U.S.A.F. operational environment regularly subject aircrew to irregular crew schedules, variable show and take-off times, disrupted/reduced sleep periods, and extended crew duty days. In addition, transmeridian flights are often associated with a 5 -6 six hour offset between the aircrew's endogenous circadian rhythm phase and the local external environmental cues. The time zone changes and shiftwork type schedules lead to significant circadian desynchrony (13). The lessons learned in the civilian workplace concerning the effects of circadian desynchrony and sleep deficit and resulting fatigue on performance are certainly applicable to the aviation community (11, 23, 24). The basic science of the circadian timing system is outlined in detail in several recently published articles (1, 14, 15, 22).

#### **Aircrew Fatigue in the Operational Environment**

Numerous articles have been published highlighting both the presence of fatigue in the operational setting and its adverse affect on aircrew performance. Rosekind et al., 1994, in association with the NASA Ames Research Center, used a diverse range of empirical measures to evaluate fatigue in the aviation environment (12). The course of this research spanned 12 years and the results have been organized into an extensive database with over 500 volunteer civilian pilots participating (with assurance of anonymity and confidentiality). The principle measures used included: background questionnaire (demographics and

personality), survey questionnaire (operational issues), logbook subjective report (pilot's daily logbook), observational/behavior data (cockpit observer log), physical performance and mental functioning tests (psychomotor vigilance test), long-term continuous recording of motor activity (actigraphy), long-term continuous recording (via Vitalog) of physiological parameters (core body temperature, heart rate), continuous physiological recording (via Medilog) of brain (EEG), eye (EOG), and muscle (EMG) activity.

The first studies effectively demonstrated that these measures could be obtained without compromising crew performance or safety. Evaluation of short haul (< 8 hours) missions revealed that pilots slept about 1.2 hours less, awoke 1.4 later, and sleep was poorer with more awakenings (compared to pretrip sleep patterns). Fatigue and negative emotions were low early and high later in the duty day. Long haul (> 8 hours) mission studies demonstrated a bimodal sleep cycle of 19 hours awake / 5.7 hours asleep and 7.4 hours awake / 5.8 hours asleep. Of note, 11% of the aircrew took naps on the flight deck – an activity not sanctioned by the FAA at the time of the study.

In light of this later finding, a study was conducted to assess the effect of a planned 40-minute cockpit rest during the low workload portion of flights across water. Rest groups and no-rest (control) groups were monitored on four consecutive legs of a regularly scheduled 12-day, eight leg trans-Pacific crossing. Compared to the rest group, the no-rest group showed performance decrements at the end of the flights, on night flights, and on the last leg compared to the first. Micro-sleeps (documented by EEG and EOG) lasting 5 seconds or longer were noted in both groups during the last 90 minutes of flight - even during descent and

landing phases of flight. The no-rest group had micro-sleeps at twice the rate as the rest group (mean of 6.7 versus 2.9 respectively). This later study was the first empirical test of a fatigue counter measure in an operational aviation setting that utilized physiological, performance and subjective measures.

Bisson et al., 1993, studied 3 C-5 transport crews during three 7-9 day trans-Atlantic missions flown in support of Operation Desert Shield in the fall of 1990 (8). Using activity logs, subjective 7-point fatigue scales, sleep surveys, and flight deck observation, the presence and factors related to acute and cumulative fatigue was assessed. Moderate and extreme fatigue was noted by many crewmembers on transoceanic flights as well as during quick turn missions from Europe to the Middle East and back. Pilots rarely slept in-flight until fatigue was moderate or more, and limited themselves to less than 2 hours in the bunk. Rarely were these naps subjectively restorative. The authors observed several instances where performance was possibly impaired by cumulative sleep loss (e.g. fumbling radio frequencies, slowed decision making, impaired judgement, diminished checklist discipline, decreased crew coordination and irritability).

Neville et al., 1994, studied the extent of fatigue in five C-141 aircrews during the final week of Operation Desert Storm and three weeks following (March and April 1991) (13). Activity logs, oral temperature readings, 7-point fatigue scales, Profile of Mood States (POMS) 0-4 fatigue factor score, and digital flight data recorder (DFDR) information on instrument landing system (ILS) approaches were measures used to assess phase of circadian cycle, fatigue, and performance. Ten or fewer hours of sleep and 15 hours or more of cumulative flight time over a 48-hour period was associated with high subjective fatigue. Cumulated flight time



over a 30-day period was not associated with increased levels of fatigue. The range of flight performance deviations on ILS approach tended to increase as subjective fatigue increased. Sleep and flight history variables showed less of an association with performance variables than did subjective fatigue. The authors noted current limits on short-term cumulative flight and sleep may not afford aircrew sufficient protection against extreme fatigue. The value of using aircrew's subjective measure of fatigue is also supported by Stoner, 1996, in studying 42 US Navy aircrew flying reconnaissance missions over Souda, Greece in 1994 (4).

Belland and Bissell 1994 surveyed US Naval aircrew during flight operations over southern Iraq in support of Operation Southern Watch in 1991 (5). Fatigue was noted to be most evident at times of decreased sensory inputs (redundant mission briefings, long monotonous flights) and least at high sensory input times (taking off, landing, or refueling).

French et al., 1994, evaluated aircrew fatigue associated with three successive and unaugmented (minimum crew size) 36 hour missions in B1-B simulators (7). The three mission profiles were similar and each was preceded by 33 to 35 hours of crew rest. Measures included cognitive performance test battery, 2 minute electrophysiologic measure, 30 second voice record, activity logs, oral temperature recordings, 7-point fatigue scale, actigraph recordings, POMS mood survey, body pain survey, as well as saliva specimens for melatonin and cortisol assays. POMS revealed that subjective fatigue, anger, confusion, depression and tension were all greater in the first mission. Vigor was the lowest on mission 3. Fatigue was greatest during mission 1 and correlated well with the nadir of oral temperature on all missions. Home based circadian cycles were maintained.

Melatonin levels did not change between missions. Cortisol levels were higher in the first mission, consistent with the increased stress reported by aircrew.

#### **Aircrew Fatigue: USAF Policy and Countermeasures**

Current Air Force Instructions (AFI) dictate that aircrews must receive adequate rest (20). The prime factors used in determining adequate rest are: total duty period, amount of sleep before the duty day's activity, and the number of hours flown during the current month. The crew rest period (free time for meals, transportation and rest) is the non-duty period immediately before the flight duty period begins. The minimum crew rest period is 12 hours. USAF aircrew are required to have at least 8 continuous hours of uninterrupted rest (defined as an opportunity to sleep without duty related interruption) during the 12 hours immediately prior to the beginning of the flight duty period. Crew rest is required to start and taxi an aircraft. The flight duty period starts when an aircrew reports for mission or briefing and ends when engines are stopped at the end of mission.

In all aircraft, when only one pilot is aboard, the maximum flight duty period (MFDP) is 12 hours. In dual control fighter, attack or reconnaissance aircraft the presence of augmented (additional) crew extends the MFDP to 16 hours. In bomber or reconnaissance aircraft the MFDP is 24 hours, extended to 30 hours if augmented crew are aboard. The maximum flying time (MFT) is 125 hours logged flight time per 30 consecutive days, and 330 hours per 90 consecutive days. MAJCOM commanders have authority to restrict or extend MFDP or MFT, but in doing so must consider the fatiguing effects of weather, extremes of temperature, complexities of mission requirements, types of aircraft flown, impaired crew rest, circadian rhythm effect, mission delays and restrictive personal equipment. The

AFI clearly states that "aircraft commanders must end a flight if safety may be compromised by fatigue factors, regardless of authorized flight duty schedules" (20).

The Aerospace Physiology Standardized Training Curriculum includes a unit on the physiology of fatigue and countermeasure strategies. This training curriculum is presented to all aircrew entering Undergraduate Pilot Training (UPT) and is repeated every three years during mandatory physiology refresher training. In addition, individual squadrons are briefed periodically by their local flight surgeons on fatigue and countermeasure strategy. An excellent briefing tool used by many flight surgeons is Alertness Management in Flight Operations. This program was developed by scientists with the NASA Ames Research Center's Fatigue Countermeasures Program in collaboration with the FAA, and is available upon request (10).

### **PURPOSE**

It is well documented that aircrew fatigue occurs in the USAF operational setting and that fatigue, an over-reaching human factor, is associated with decrements in aircrew performance (7,8,13). To fully understand the impact of fatigue in the USAF operational environment, one must first establish its overall incidence. The purpose of this study was to investigate the incidence of subjective fatigue in the USAF operational environment. This is the first study to date, specifically designed to evaluate the incidence of fatigue in the USAF operational environment.

## **METHODS AND MATERIALS**

The design strategy used was that of a prospective cohort study. By definition the study will be determining incidence, i.e. new "cases" of fatigue occurring in the operational setting. This study examined those pilots and flight engineers that regularly fly long transport missions. The specific study group included all pilots and flight engineers belonging to the United States Air Force Reserves' (USAFR) 68<sup>TH</sup> Airlift Squadron (AS) stationed at Kelly AFB, TX. This squadron has approximately 65 pilots and 70 flight engineers and flies the C-5 Galaxy transport aircraft exclusively. No local missions were included in the study because of their brevity (duration of 4 hours or less).

Study tools utilized for data collection were drafted specifically for this study and included a premission questionnaire (appendix 3), a postmission questionnaire (appendix 4), and a mission log (appendix 5). To optimize form and function, each of these tools were revised/refined several times prior to actual use. Valuable review and feedback was obtained from both research physiologist, Jonathan French PhD, at the Crew Systems Directorate, Sustained Operations Branch, Armstrong Laboratory at Brooks AFB, Texas as well as Major Rene Bergeron, Safety Officer, 433<sup>rd</sup> Airlift Wing. A study tool kit consisted of one premission questionnaire, one postmission questionnaire, two mission logs, a self-addressed manila envelope, a cover letter (appendix 7), and letter of information (appendix 8). The latter two were stapled to the manila envelope, which contained the study tools. The envelope was of such a size as to readily fit into the pockets of a flight suit.

The proposal for this study was submitted to and approved by the Advisory Committee for Human Experimentation at Brooks AFB, TX as well as the Committee for the Protection of Human Subjects, University of Texas at Houston School of Public Health (Appendices 10 and 11). The study was accomplished in conjunction with Dr Jonathan French. At the squadron level, efforts were coordinated with Col O'Toole, 68<sup>TH</sup> Medical Squadron Commander. After personal interviews, approval was granted by both the 433<sup>rd</sup> Airlift Wing commander and the 68<sup>th</sup> Airlift Squadron commander (Appendix 9). A formal squadron level briefing was accomplished to explain the study to all members on 8 February 1998 (Appendix 6).

Immediately following the briefing, a study tool kit was placed in the vertical file (the V-file or "mail box") of each pilot and flight engineer assigned to the 68<sup>th</sup> ALS. This distribution site was selected after consultation with Major Bergeron and several other pilots and flight engineers. By squadron policy V-files should be checked frequently (at minimum before each mission) and they are optimally located in the squadron's mission briefing room (the location of all mission briefings and debriefings). In addition, a set of extra study tool kits were conspicuously placed in a clearly labeled open-top file box on top of the file cabinet containing the V-files. A clearly marked folder for completed forms was also present.

Premission and postmission questionnaires were completed prior to and at mission completion respectively. Throughout the mission, the study subjects completed a mission log. This mission log tracked type of activity, serial fatigue rating, and place of sleep. Subjective fatigue was rated starting at mission onset,

every four hours throughout the mission and at mission completion, that is, at time of engine shut down. Full (and simple) instructions for its use were contained on the mission log form.

Fatigue was measured using the School of Aerospace Medicine (SAM) fatigue scale. This scale ranges from one to seven as follows:

- 1 = Fully alert, wide awake, very peppy
- 2 = Very lively, responsive, not at peak
- 3 = Okay, somewhat fresh
- 4 = A little tired, less than fresh
- 5 = Moderately tired, let down
- 6 = Extremely tired, very difficult to concentrate
- 7 = Completely exhausted, unable to function

The case definition for fatigue was any rating of 4 or above. These were graded as mild (rating of 4), moderate (rating of 5) and severe (rating of 6 or 7).

No physiologic measurements were taken during the study.

Strict confidentiality was maintained by all. All questionnaires were placed in the manila envelope and sealed by the study subject (pilot or flight engineer) immediately after completion of post-mission questionnaire. These were then returned to the above noted return folder or placed in Major Bergeron's V-file at the time of mission debriefing. The author collected the sealed envelopes on a weekly basis during February and March 1998. Personal identifiers (name, SSAN etc.) were not used at any time. The study as designed had no impact on cockpit resource management, mission completion, mission safety or pilot health.

## RESULTS

Of the 135 study kits placed in the V-files, six were returned. Of these, four were completed by pilots and two by flight engineers. All six responders completed the pre and postmission questionnaires but only three (one pilot and two flight engineers) completed the mission log.

Study subjects reported to sleep an average of 7.5 hours and 5.75 hours in the respective 24 hour and 12 hours periods immediately prior to mission onset. Mean fatigue rating immediately prior to mission onset was 2.16. However, excluding one outlier rating of 5, the other five participants had a mean premission fatigue rating of 1.5.

All participants reported experiencing a fatigue rating of five or more on at least some of previous missions flown. The frequency ranged from 10 to 60 percent of previous missions flown with a mean of 36.66 percent. None of those surveyed could recall the last time a flight surgeon had discussed aircrew fatigue with them on either a formal or informal basis. Four of six responders were able to list more than one known fatigue countermeasure (Table 1). Mean compliance with current AFI directives for crew rest was reported to be 93 percent for self and 87.5 percent for others.

Fatigue ratings of four (mild), five (moderate) and six (severe) were reported five, eight and six times during the 105 hours of actual flight time accumulated by the three responders completing the mission logs. All three responders completing the mission log reported at least one fatigue rating of six (severe) while engaged in active flight (Figure 1). None reported a fatigue rating of seven at any time. In

summary, these aircrew reported eighteen episodes of fatigue (mild to severe) during 105 hours of actual flight time.

All responders reported that their mood, concentration, reaction time, crew resource management (CRM), and ability to retain new and old information were all adversely affected by fatigue at some point during the actual flying portion of their mission (Figure 2). In fact, the mean score for degree of impairment revealed mild to moderate impairment of function in all of these variables (Figure 2). Three of four pilots and both engineers reported that fatigue subjectively affected their performance. Missed radio calls and lack of concentration were noted as specific examples of how performance was impaired. The aircrew responding cited numerous factors that contributed to their fatigue (Table 2). Four of six responders reported utilizing at least one fatigue countermeasure at some time during their mission to combat fatigue (Table 3).

Four of six aircrew responded when asked their recommendation on what would be adequate crew rest following maximum regular (non-augmented) and augmented crew missions. For regular (non-augmented) missions, suggested adequate minimum crew rest following maximum duty day (16 hours) was felt to be either 18 or 20 hours (mean 19 hours). For augmented missions, suggested adequate minimum crew rest following maximum duty day (24 hours) ranged from 20 to 30 hours (mean 23.5 hours).

## **DISCUSSION**

Up front, it was recognized that this study was going to require continued buy-in from the pilots and flight engineers in the squadron. The biggest weaknesses in this study were forecasted to be obtaining suitable participation



from the study subjects during the actual missions as well as loss of data due to lack of follow-up on part of the participants. During the study period (February and March of 1998) the 68<sup>th</sup> Airlift Squadron flew 14 air lift missions that were suitable for inclusion in this study. Fortuitously, for this purpose of this study, all of these missions were actual operational missions flown to the Persian Gulf in support of Operation Phoenix Scorpion II. An investigator wanting to study aircrew fatigue in the operational setting could not have wished for a better set of circumstances. A total of 37 pilots and 28 flight engineers took part in these operational missions. Ideally, these missions should have generated 65 responses, encompassing an estimated 2,275 hours of actual operational flight time (65 responders X an average of 35 hours of flight time per mission). The return of only 6 responses encompassing 105 hours of flight time (representing less than a 10 percent return) was, to say the very least, disappointing.

Attempting to analyze, in retrospect, why the participant response was so poor is a difficult yet necessary task. Initial introduction to the 68 Airlift Squadron was accomplished through the 433<sup>rd</sup> Aerospace Medical Squadron commander. He was very receptive and assisted me in receiving the 433<sup>rd</sup> Airlift Wing and 68<sup>th</sup> Airlift Squadron commanders' permission to do the study. Once granted, contact with the 433<sup>rd</sup> Airlift Wing safety office was made and was very well received. They were staunch supporters of the efforts and assisted in every aspect. The squadron was briefed at the monthly safety meeting (mandatory for all squadron members) in February, immediately prior to the start of the study. A repeat briefing was accomplished during the March safety meeting as well. The reception from the aircrew at the briefings was lukewarm at best (a fairly typical response to an

"unknown" in their midst). This lack of familiarity most likely contributed to the poor response. Another drawback in trying to brief members of an USAF reserve squadron is that only the aircrew on active reserve time at the time of the monthly safety meetings actually attend the meetings. It could take a year of monthly briefings before all aircrew rotated through the squadron's monthly safety briefings. Furthermore, I discovered that attendance at these mandatory meetings is not always a hundred percent, even for those on active reserve time. Following the suggestion of the safety officer and several other pilots, the study tool kit was placed in the V-files. A cover letter (signed by the safety officer and myself) as well as a letter of information was attached to the study tool kit in order to inform any aircrew not in attendance at the safety meeting briefings as to the nature of the study.

The study tools were carefully designed to minimize participant time and effort. The pre and postmission questionnaires were each consolidated into a single sided page (prior documents used by other investigators had been as much as six pages each). All six of the responders completed both the pre and post mission questionnaire. The mission log, although somewhat busy, was also consolidated to one side of a page. Two of these were included in the study tool kit for extra long missions (covering more than seven days). Only three of six responders completed the mission log. One responder scribbled on the mission log "this is too much of a hassle to do during an operational mission". The mission log may need further revision before use in future studies.

The past five years has seen a marked reduction in force in the USAF due to downsizing and pilot attrition. These factors coupled with increased operational

tempo have put a significant strain on USAF aircrew. The finding in their V-file of another tasking, no matter how stream-lined and well intentioned, may have been seen as just more non-mandatory paperwork that they did not have the time, energy, or will to accomplish. A definite limitation in gaining compliance was the fact that the author was not a member of their "flying community" and did not actually fly with them. A researcher's (in this case a flight surgeon) presence in the cockpit goes a long way in assuring compliance. This was clearly illustrated in the work of Rosekind et al, Bisson et al, Neville et al, and French et al (12, 8, 13, 7). Each of these investigators enhanced aircrew compliance by the presence of members of the research team in the cockpit. Despite being a fully qualified flight surgeon, the author's request to fly on as many of these missions as possible was turned down by the wing commander. He simply stated that because of the operational nature of the missions, no flight surgeons were being permitted to fly.

Although the flight safety officer reported that fatigue was a very common aircrew complaint brought to his office, he was unsure why so few aircrew responded. To answer this question, consideration was given to surveying the 135 aircrew participants in order to gain direct feedback. However, the names, addresses and phone numbers could not be recovered due to the privacy act. Furthermore, such a disclosure may very well have violated the initial agreement with the participants that this would be a purely voluntary and confidential study with no use of personal identifiers. They may have seen a phone survey or mail survey of this nature as a violation of the aforementioned agreement.

The purpose of this study was to determine the incidence of USAF aircrew fatigue in the operational environment. Three aircrew mission logs with only 105

total hours of flight time certainly does not permit any generalizations regarding fatigue in the operational environment to the C-5 aircrew community at large. However, it is noteworthy that all three aircrew experienced a fatigue rating of six (severe fatigue) at least once while flying their missions. A fatigue rating of 5 or more (moderate to severe fatigue) was reported 14 times in 105 hours of flight time. In addition, all six aircrew responding reported that their mood, concentration, reaction time, CRM, and ability to retain new and old information were mild to moderately affected at some point while flying their missions. This, together with Neville et al's finding of significant correlation between flight performance and subjective fatigue rating in the moderate to severe range, should prompt further studies to determine the actual incidence of fatigue and its impact on aircrew performance in the USAF operational environment (13).

Although it is less clear at this time the direct impact of fatigue on flight safety, it certainly is an over-arching human factor affecting the relationship between man, the aircraft and the environment. Despite the improvement in overall flight safety over the past 20 years, the percentage of mishaps due to human error (as a result of a breakdown in one or more human factors) has remained constant. It is noteworthy that none of the six responding aircrew could remember the last time a flight surgeon (the squadron's expert in flight safety) discussed fatigue. Another intriguing bit of information was that all responders felt the minimum current crew rest requirements after maximum non-augmented and augmented crew duty days should be increased. The inference here is that the aircrew flying these missions feel the current minimum crew rest times are insufficient to insure proper recovery.

Although the small number of responders in this study limits one's ability to make any statistically significant inference relative to the general population of USAF C-5 pilots flying operational missions, the study does serve as a valuable pilot study. It certainly highlights some pitfalls (lessons learned) in data collection in the USAF operational environment and provides useful information that can be utilized in future research endeavors.

### **CONCLUSION**

Future studies are essential to determine the incidence of USAF aircrew fatigue in the operational environment in order to fully understand its overall impact on aircrew performance, its impact on flight safety, and the need to invest in the development of specific countermeasures.

Data collection in the USAF operational environment is very difficult. It is imperative to take this into account in the design of future studies. A flight surgeon assigned to the unit participating in the study or a member of the research team should accompany the participants on the actual flying missions to enhance compliance with data collection.

## Appendix 1: Tables

Table 1

Fatigue Countermeasures Listed by C-5 Aircrew
Restful sleep and short naps
Eating
Exercising
Drinking coffee
Abstaining from alcoholic beverages
Use of bright lights

Table 2

Contributing Factors Leading to Aircrew Fatigue as Noted by Aircrew
Crossing multiple time zones at all hours of the day and night
Unpredictability of when crew would be called to alert status
Lousy launch (show) times
Being in a contingency (real world) operational mode
Crew rest quarters nonconducive to sleep because of noise
Not beng able to enter "full" REM sleep
Back to back twenty hour days

Table 3

Fatigue Countermeasures Utilized by C-5 Aircrew
Accomplish busy-work in seat
Get out of seat and move around
Move around in seat
Eat
Drink coffee
Nap (with ear plugs)

## Appendix 2: Figures

Figure 1. Episodes of Subjective Fatigue in C-5 Aircrew

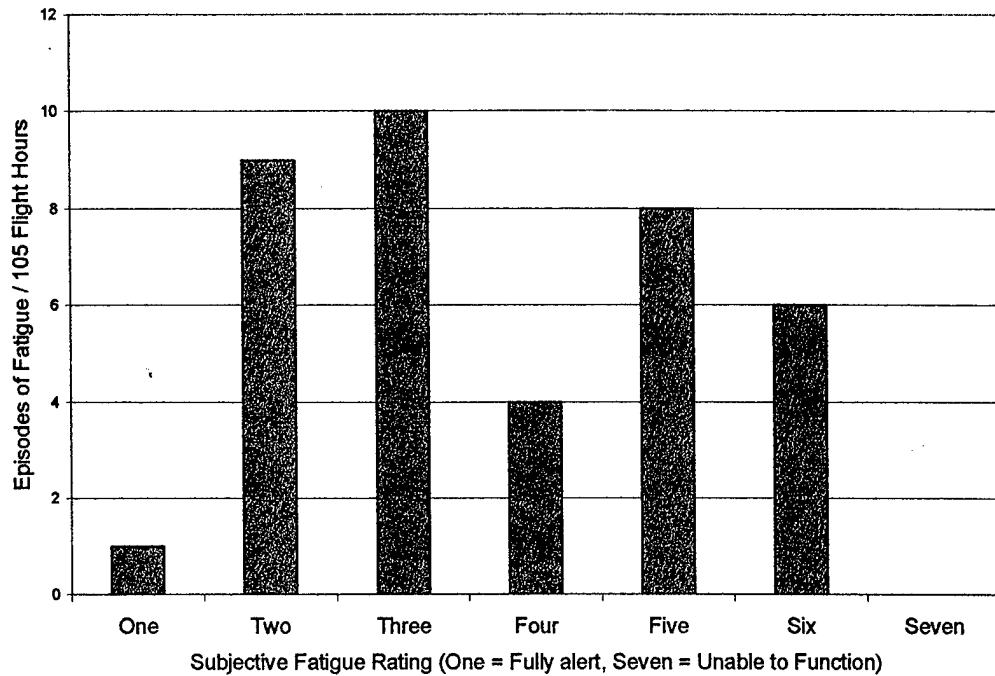
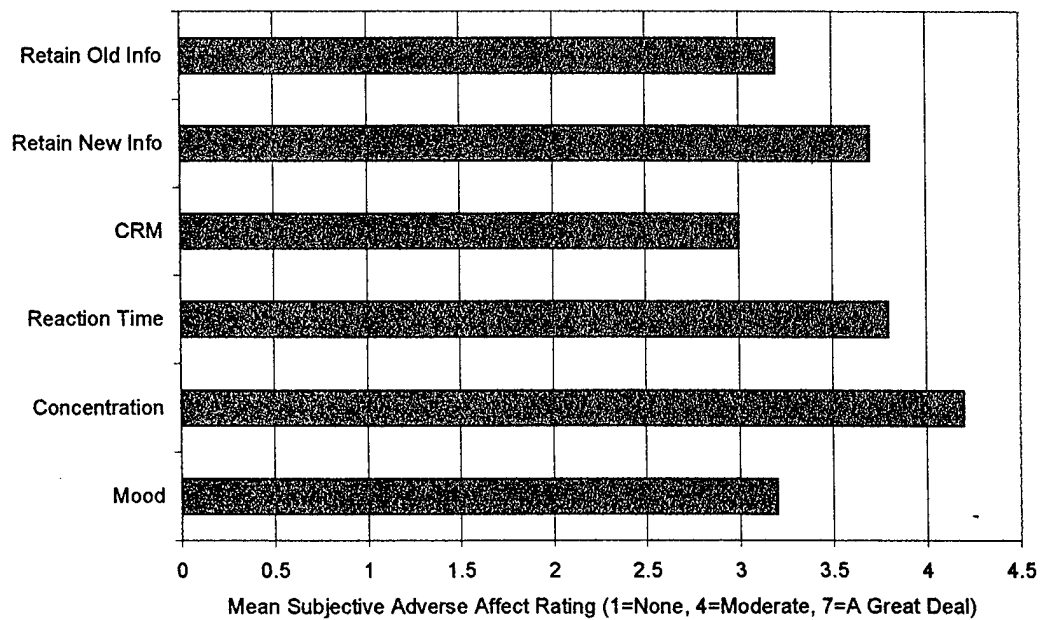


Figure 2. Adverse Affect of Fatigue on Selected Human Factors



### Appendix 3: Premission Questionnaire

#### C-5 AIRCREW FATIGUE STUDY PREMISSION QUESTIONNAIRE

Study ID #: \_\_\_\_\_ Crew Position: A/C CP E Mission Start Date: \_\_\_\_\_

- 1 How many hours of sleep have you had in the last 24 hours? \_\_\_\_\_
- 2 How many hours of sleep did get during your 12 hour crew rest? \_\_\_\_\_
- 3 When you awoke from your last period of sleep how did you feel? \_\_\_\_\_  
1 = Well Rested                      3 = Slightly Rested  
2 = Moderately Rested              4 = Not At All Rested
- 4 How would you rate you level of fatigue at this time? \_\_\_\_\_  
1 = Fully Alert, Wide Awake, Very Peppy  
2 = Very Lively, Responsive But Not at Peak  
3 = Okay, Somewhat Fresh  
4 = A Little Tired, Less Than Fresh  
5 = Moderately Tired, Let Down  
6 = Extremely Tired, Very Difficult to Concentrate  
7 = Completely exhausted, Unable to Function
- 5 On what percentage of past missions have you experienced a fatigue level of 5 or more while flying (0%, 10%, 20%, 30%, 40%, 50% etc.)? \_\_\_\_\_
- 6 When did your flight surgeon last discuss aircrew fatigue? \_\_\_\_\_
- 7 List known countermeasures useful in combating aircrew fatigue? \_\_\_\_\_  
(Note: This question is not designed to nail you but rather to see if we flight docs are doing our job! Thanks) \_\_\_\_\_
- 8 In your estimation, what is the overall compliance rate with current ... Self \_\_\_\_\_  
AFI directives regarding crew rest? (100%, 90%, 80% etc.) Others \_\_\_\_\_

If Lost Return To: 433rd AW/SE 203 Galaxy Rd Kelly AFB TX 78241 (DSN 969-3988/COMM 210-977-3988)  
Your assistance is appreciated Results are confidential No personal identifiers to be used



## Appendix 4: Postmission Questionnaire

### C-5 AIRCREW FATIGUE STUDY POSTMISSION QUESTIONNAIRE

Study ID #: \_\_\_\_\_ Crew Position: A/C CP E Mission End Date: \_\_\_\_\_

1 While you were flying, were any of the following adversely affected by fatigue?

		Not At All			Moderately		A Great Deal	
* Y O U R	Mood	1	2	3	4	5	6	7
	Concentration	1	2	3	4	5	6	7
	Reaction Time	1	2	3	4	5	6	7
	CRM	1	2	3	4	5	6	7
*	Retention New Info	1	2	3	4	5	6	7
*	Retrieval Old Info	1	2	3	4	5	6	7

2 Did you feel that fatigue adversely affected your level of performance at any time while flying during this mission (please circle)? Yes No

If yes, please briefly explain: \_\_\_\_\_  
\_\_\_\_\_

3 If you experienced fatigue while flying, what were the important contributing factors?

\_\_\_\_\_  
\_\_\_\_\_

4 If you experienced fatigue while flying, what did you do to alleviate your fatigue?

\_\_\_\_\_  
\_\_\_\_\_

5 Did anything prevent you from getting restful sleep on this mission? Yes No

If yes, please briefly explain: \_\_\_\_\_  
\_\_\_\_\_

6 Given your experience, how much crew rest should you be given after a maximum crew duty day (ie number of hours before the next departure leg)?

Reg(16h) \_\_\_\_\_

Aug(24h) \_\_\_\_\_

7 Additional comments:

*If Lost Return To: 433rd AW/SE 203 Galaxy Road Kelly AFB TX 78241 (DSN 969-3988/COMM 210-977-398)  
Your assistance is appreciated Results are confidential No personal identifiers to be used*

# Appendix 5: Mission Log

Karl E Lee, Lt Col, USAF, MC, FS  
Home Ph # 210-478-7254  
Cell Ph # 210-882-1717

## C-5 AIRCREW FATIGUE STUDY MISSION LOG

STUDY ID #: CREW POSITION: A/C CP E  
MISSION START DATE:

DATE:	TIME (ZULU) >>>	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400
ACTIVITY CODE (S<->S or F<->F)																									
FATIGUE RATING (1 to 7)																									
PLACE OF SLEEP																									
DATE:	TIME (ZULU) >>>	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400
ACTIVITY CODE (S<->S or F<->F)																									
FATIGUE RATING (1 to 7)																									
PLACE OF SLEEP																									
DATE:	TIME (ZULU) >>>	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400
ACTIVITY CODE (S<->S or F<->F)																									
FATIGUE RATING (1 to 7)																									
PLACE OF SLEEP																									
DATE:	TIME (ZULU) >>>	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400
ACTIVITY CODE (S<->S or F<->F)																									
FATIGUE RATING (1 to 7)																									
PLACE OF SLEEP																									
DATE:	TIME (ZULU) >>>	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400
ACTIVITY CODE (S<->S or F<->F)																									
FATIGUE RATING (1 to 7)																									
PLACE OF SLEEP																									
DATE:	TIME (ZULU) >>>	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400
ACTIVITY CODE (S<->S or F<->F)																									
FATIGUE RATING (1 to 7)																									
PLACE OF SLEEP																									

**INSTRUCTIONS FOR COMPLETION:** Please record your Fatigue Rating at the beginning and end of each leg and every four hours during each leg of the mission.

**SUBJECTIVE FATIGUE SCALE:** As noted above, while awake record number that best describes your level of fatigue in the appropriate block above.

1 = Fully Alert, Wide Awake, Very Peppy  
2 = Very Lively, Responsive, Not at Peak  
3 = Okay, Somewhat Fresh  
4 = A Little Tired, Less Than Fresh  
5 = Moderately Tired, Let Down  
6 = Extremely Tired, Very Difficult to Concentrate  
7 = Completely exhausted, Unable to Function

**UPON AWAKENING:** Indicate the quality of sleep obtained and record the number just after the 2nd S (eg S<->S 2)

1 = Well Rested  
2 = Moderately Rested  
3 = Slightly Rested  
4 = Not At All Rested

Please Remember: Use Zulu time; Keep this page handy (fold and put into flight suit etc.). At end of mission place this page and the pre & post mission questionnaires in envelope provided, seal, and return to 433rd AW/SE.

If Lost Return To: 433rd AW/SE 203 Galaxy Rd Kelly AFB TX 78241-5554 (DSN 869-3988/ COMM 210-877-3988) ATTN Maj Rene Bergeron or Maj Ben Ratliff

## Appendix 6: Squadron Briefing Slides

### *Incidence of Aircrew Fatigue in the Operational Setting*

A Briefing to the 68th Airlift Squadron

Karl E Lee, Lt Col, USAF, MC, FS  
8 February 1998

### *Incidence of Aircrew Fatigue in the Operational Setting*

- Briefing Outline
  - Introduction and a Word of Thanks
  - Why I Think Fatigue is Important
  - Aircrew Fatigue in the USAF
  - The Nuts and Bolts of this Study Protocol
    - What I Am Asking You To Do
  - Wrap Up

### *Incidence of Aircrew Fatigue in the Operational Setting*

- Today's technological society demands a 24 hour operational environment
- Health care, manufacturing, and transportation industries as well as public safety/service and military organizations all rely on around the clock operations

### *Incidence of Aircrew Fatigue in the Operational Setting*

- In the US, twenty million (1 in 5) full-time workers are shift-workers
- This group experiences disrupted physiology, social activities, and family life
- Physiological disruption occurs in the areas of sleep and circadian rhythm

### *Incidence of Aircrew Fatigue in the Operational Setting*

- Cumulative sleep loss and circadian disruption can lead to decreased waking alertness, impaired performance and worsened mood (i.e. fatigue)
- Human error responsible for:
  - 65-90% of all transportation accidents
  - 65% of all jet transport accidents
  - ? % of all industrial accidents (i.e. Exxon Valdez, Three Mile Island, & Bhopal accidents)

### *Incidence of Aircrew Fatigue in the Operational Setting*

- The Human Factor in Flight & Human Error
  - Aviator < Aircraft > Environment
  - Training, proficiency, currency, experience, judgement, decision making, motivation, physical fitness, stress, nutrition and fatigue
- USAF 1995
  - 33 Class A Mishaps      29 Aircraft Lost
  - 53 Fatalities      Mishap Rate 1.5
  - 71% Class A mishaps due to human error

### *Incidence of Aircrew Fatigue in the Operational Setting*

- The Purpose of this Study:
  - Determine the incidence of aircrew fatigue in the USAF operational environment
- Your Role as a Study Subject
  - Is voluntary
  - Is confidential (no personal identifiers)
  - Is streamlined to require minimal time & effort
  - Is critical to the success of the study

### *Incidence of Aircrew Fatigue in the Operational Setting*

- Study Tools:
  - Permission Questionnaire
  - Mission Log
  - Postmission Questionnaire
- Methodology
  - Study tools to be placed in V-File
  - Completion of Study Tools
  - Return to Major Rene Bergeron

### *Incidence of Aircrew Fatigue in the Operational Setting*

- Duration of Study
  - February and March 1998
- Types of Mission
  - No Locals
- Follow Up
  - Post-Study Debrief
  - Post-Study Presentation on Fatigue
  - Future Studies / Initiatives

### *Incidence of Aircrew Fatigue in the Operational Setting*

- Wrap Up
  - Fatigue happens
    - Need to know how often
  - Fatigue is important in the operational setting
    - Need to know how important
  - Fatigue can be lessened
    - Need effective countermeasures
  - We can make a difference
    - Need your help and cooperation - thank you

## Appendix 7: Cover Letter

9 Feb 98

### MEMORANDUM FOR RECORD

FROM: Karl E Lee, Lt Col, USAF, MC, FS  
Rene Bergeron, Maj, USAFR, Chief of Safety

TO: Pilots and Flight Engineers  
68<sup>th</sup> Airlift Squadron

SUBJECT: Aircrew Fatigue Study

1. As briefed in the Flying Safety meeting on 8 February 1998, the 68<sup>th</sup> Airlift Squadron is being asked to participate in study to determine the incidence of aircrew fatigue in the operational environment.
2. The USAF has seen, in the 1990's, a reduction in aircrew and airframes without a corresponding decrease in operational tempo. Given this setting, it is imperative that we look diligently at the issue of fatigue – an overarching human factor in the complex interaction between the aviator, the aircraft and the environment. The first step (and the purpose of this study) is to determine its incidence, i.e. how often it occurs. Once determined, we can then look at its affect on performance and investigate specific countermeasures to lessen its impact.
3. The study is limited to pilots and flight engineers and involves completing a brief premission questionnaire, an in-flight mission log, and a postmission questionnaire. The pre and postmission questionnaires are self-explanatory and the in-flight mission log has instructions provided at the bottom of the form. Much thought has gone into streamlining these forms in order to minimize your time and effort in their completion – any feedback on how we could further improve them is welcome.
4. Your cooperation is essential in completing this study and is greatly appreciated. We would ask the A/C's to encourage the aircrew's participation during the pre-flight briefing and remind them to return the completed forms at the end of the mission.
5. At mission completion, please place all forms in the envelope provided, seal, and return to the 433<sup>rd</sup> AW/SE.
6. Thank you for helping to make the operational flying environment safer.

RENE BERGERON  
Major, USAFR, Chief of Safety  
FS

KARL E. LEE  
Lieutenant Colonel, USAF, MC,  
FS

## Appendix 8: Letter of Information

### LETTER OF INFORMATION

TITLE OF STUDY: Incidence of USAF Aircrew Fatigue in the Operational Setting

1. Purpose: You have been asked to volunteer as a participant in the above named project. The purpose of this study will be to investigate the incidence of subjective fatigue in the USAF operational environment.

2. Experimental Procedures: You will be asked to participate by completing a one page pre-mission and a one page post-mission questionnaire prior to mission and at mission completion respectively. You will also be asked to complete throughout the mission, a mission log. This mission log will track type of activity, serial fatigue rating, and place of sleep. Subjective fatigue will be rated starting at the onset of the mission &/or individual leg of the mission, every four hours throughout the mission &/or individual leg of the mission, and at completion of the mission &/or individual leg of the mission (i.e. engine shutdown). Fatigue will be measured using the School of Aerospace Medicine (SAM) 7 point fatigue scale - a copy of which is at the bottom of the mission log sheet. At final mission completion the above documents will be placed in the envelope provided, sealed and returned as directed.

3. Time Requirement: Estimate maximum of five minutes to complete the pre and post mission questionnaires and no more than a minute for each set of notations made on the mission log (maximum of 5 sets of notations).

4. Discomfort and Risk to Participants: Study as designed will have no impact on cockpit resource management, mission completion, mission safety or pilot health. No significant discomfort or risk to participants foreseen.

5. Benefits:

a.) You will not benefit personally (directly) by participating in this study.

b.) You will be helping to expand the scientific knowledge of aircrew fatigue, given that the incidence of fatigue has not been directly studied in the USAF operational environment. There is no other way to gather this information except by study it in the operational setting.

6. Entitlements and Confidentiality:

a.) Records of your participation in this study may only be disclosed according to Federal Law, including the Federal Privacy Act, 5 U.S.C.552a, and it's implementing regulations. At no time during this study will personal identifiers (name, SSAN etc.) be used.

b.) If you desire further information you may contact: Lt Col Karl Lee, USAF, MC, FS (210-479-7254 or 210-862-1717); Maj Rene Bergeron or Maj Ben Ratliff, 433<sup>rd</sup> WS/SE (DSN 969-3988/COMM 210-977-3988); Jonathan French Ph.D., Crew Systems Directorate/Sustained Operations Branch, Brooks SFB (DSN 240-8140/COMM 210-536-8140); Committee for the Protection of Human Subjects, UT at Houston (713-500-9053).

c.) The decision to participate in this research is completely voluntary on your part. No one will coerce or intimidate you into participating in this study. You will participate only because you want to.

I, Lt Col Lee, will answer any and all questions you may have about this study, your participation, and the procedures involved. Please understand that you may withdraw from the study at any time and discontinue further participation without prejudice.

INVESTIGATOR SIGNATURE: \_\_\_\_\_

Karl E Lee, Lt Col, USAF, MC, FS

DATE: \_\_\_\_\_

Appendix 9: 433<sup>rd</sup> Airlift Wing Approval Letter

**433<sup>rd</sup> MEDICAL SQUADRON**

203 Galaxy Road  
Kelly AFB, Texas 78241-5554

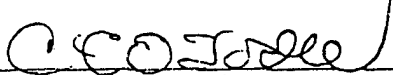
DATE: January 15, 1998

SUBJECT: Air Crew Fatigue Study

TO: AL/CFTO Brooks Air Force Base, Texas

FROM: Col Charles L. O'Toole  
Commander 433<sup>rd</sup> Medical Squadron

1. Lt Col Karl Lee has approached the 433<sup>rd</sup> Airlift Wing on an Air Crew Fatigue Study.
2. This issue has been brought forward and discussed with Col Peter T. Bentley, 433<sup>rd</sup> Airwing Commander, and with Lt Col Ed Dingvar, Commander 68<sup>th</sup> Air Lift Squadron at the 433<sup>rd</sup> Airlift Wing. Both concur and agree with participation in the study at this point.
3. The 433<sup>rd</sup> Medical Squadron has agreed to assist and help Col Lee in any manner that we may with producing and continuing the study.
4. It has been cleared that Lt Col Lee will be allowed to present and set up this program at a flying safety meeting of the 68<sup>th</sup> Airlift Squadron at a future date.
5. If you have any additional questions, please feel free to contact me at 433<sup>rd</sup> Medical Squadron  
Kelly Air Force Base, Texas  
DSN 969-5341  
Commercial 210-977-5341  
or Civilian Office  
817-573-8805

  
C.L. O'Toole, Col USAFR, MC, FS  
Commander 433<sup>rd</sup> Medical Squadron

## Appendix 10: Advisory Committee for Human Experimentation Request

### EXPERIMENTAL PROTOCOL Incidence of U.S.A.F. Aircrew Fatigue in the Operational Setting

1. PROJECT/TASK/WORK UNIT:
2. PRINCIPAL INVESTIGATOR: Jon French, Ph.D.  
Armstrong Laboratory/CFTO x3464
3. CO-PRINCIPAL INVESTIGATORS: Karl Lee, Lt Col, USAF, MC, FS  
UTHSCSA, School of Public Health
4. MEDICAL CONSULTANT: Chief, Aerospace Medicine  
Armstrong Laboratory  
Brooks AFB TX
5. CONTRACTOR: Not applicable
6. OBJECTIVE: Though subjective fatigue measures have been utilized in assessing aircrew fatigue, none have attempted to establish its overall incidence in the USAF flying community. The purpose of this study will be to investigate the incidence of subjective fatigue in the USAF operational environment. The specific research question to be answered is: What is the incidence of subjective aircrew fatigue in the USAF operational environment?
7. BACKGROUND AND RELEVANCE: The United States Air Force flying community is currently composed of 14,457 pilots and 5,482 navigators partitioned out to one of 90 wings still in existence within one of the 17 remaining Numbered Air Forces. They are assigned to any one of 75 CONUS or 20 overseas bases from which they operate on a 24-hour readiness schedule (19). The U.S.A.F. aviation community has seen, in the 1990's, a reduction in manning and aircraft without corresponding changes in operational tempo (17). This streamlined air force is faced with defending U.S. national interests in support of our global reach, power, and engagement policies. Long range and continuous air operations are thus a common challenge for aircrews.  
The USAF, like the DoD overall, has seen its aviation safety record improve dramatically over the past 20 years. Annual figures from 1975 through 1995 show a decrease in Class A mishaps from 99 to 33, aircraft destroyed from 52 to 29, fatalities from 141 to 53, and mishap rate from 2.8 to 1.5 (17). Although gains have been made in decreasing mishaps due to material causes (system and mechanical failure), human error continues to account for the majority of all mishaps - 71 percent from 1990 to 1995 (17).  
The term human factor in aviation is defined in various ways by different authors (18). The most common use of the term denotes the relationship between the aviator, the



aircraft, and the environment. This term encompasses a complex group interrelated factors to include training, proficiency, currency, experience, judgement, decision making, motivation, physical fitness, physiology, personal stress, nutrition, and fatigue (18). It is a disturbance/imbalance of one or more of these factors in the flight environment that leads to human error ■ the most common cause of aircraft mishaps. The degree to which each factor contributes to cause will vary from mishap to mishap. In light of what is known with regards to fatigue and performance, it is hard to imagine that the presence of fatigue could not be directly causal or at least exacerbate human error due to a combination of any of the human factors listed above. Indeed, analyses of confidential reports to the NASA Aviation Safety Reporting System indicated approximately 21 percent of all reported incidents are fatigued related (3).

Mission requirements in the current U.S.A.F. operational environment regularly subject aircrew to irregular crew schedules, variable show and take-off times, disrupted/reduced sleep periods, and extended crew duty days. In addition, transmeridian flights are often associated with a 5 ■ 6 six hour offset between the aircrew's endogenous circadian rhythm phase and the local external environmental cues. The time zone changes and shiftwork type schedules lead to significant circadian desynchrony (13). The lessons learned in the civilian workplace concerning the effects of circadian desynchrony and sleep deficit and resulting fatigue on performance are certainly applicable to the aviation community (11, 23, 24). The basic science of the circadian timing system is outlined in detail in several recently published articles (1, 14, 15, 22).

Numerous articles have been published highlighting both the presence of fatigue in the operational setting and its adverse affect on aircrew performance. Rosekind et al, 1994, in association with the NASA Ames Research Center, used a diverse range of empirical measures to evaluate fatigue in the aviation environment (12). Bisson et al 1993, studied 3 C-5 transport crews during three 7-9 day trans-Atlantic missions flown in support of Operation Desert Shield in the fall of 1990 (8). Neville et al 1994, studied the extent of fatigue in five C-141 aircrews during the final week of Operation Desert Storm and three weeks following (March and April 1991) (13). Belland and Bissell 1994, surveyed US Naval aircrew during flight operations over southern Iraq in support of Operation Southern Watch in 1991 (5). French et al 1994, evaluated aircrew fatigue (32 operationally qualified crew) associated with successive and unaugmented 36 hour missions in B1-B simulators (7).

8. IMPACT STATEMENT: It is well documented that aircrew fatigue occurs in the operation setting. It is also well documented that fatigue, an over-reaching human factor is

associated with decrements in aircrew performance that can lead to human error. In that human error is implicated in 71% of recent USAF mishaps, there is a considerable amount to gain from further quantifying fatigue in the operational setting. The overall incidence of fatigue must be established before we can ascertain the true magnitude of its overall impact on aircrew performance, mission completion, and safety. This information will be valuable in directing further studies to evaluate potential aircrew fatigue countermeasures in the operational setting.

9. EXPERIMENTAL PLAN: The study design will be submitted to the Advisory Committee for Human Experimentation (ACHE) at Brooks AFB for approval.

Methods and procedures

*Study Design:* The design strategy to be used will be a prospective cohort study. By definition the study will be determining incidence, i.e. new **cases** of fatigue occurring in the operational setting.

Epidemiologic Study Setting

*Who:* This study will look specifically at those pilots who regularly fly long transport missions. The specific study group will include all pilots belonging to the 68<sup>th</sup> Airlift Squadron (AS) stationed at Kelly AFB, TX. This squadron has approximately 60 pilots and flies the C-5 Galaxy transport aircraft exclusively.

*How:* This study will be accomplished in conjunction with the Crew Systems Directorate, Sustained Operations Branch, Armstrong Laboratory at Brooks AFB, TX. Author will be working directly with research physiologist, Jonathan French, Ph.D. At the squadron level, efforts are being coordinated with Col O'Toole, 68<sup>th</sup> Medical Squadron Commander. Verbal approval has been obtained from the 433<sup>rd</sup> Airlift Wing and 68<sup>th</sup> Airlift Squadron commanders **written confirmation pending**. Squadron briefings are being scheduled to explain study to all members.

*What:* The dependent variable is subjective fatigue. The independent variables are the number of hours slept during the 24-hour and 12-hour periods immediately prior to mission flown and pilot compliance with crew rest. Pre and post-mission questionnaires will be completed prior to and at mission completion respectively (attachments 1 and 2). Throughout the mission, the study subjects will complete a mission log (attachment 3). This mission log will track type of activity, serial fatigue rating, and place of sleep. Subjective fatigue will be rated starting at mission onset, every four hours throughout the mission and at mission completion, that is, at time of engine shut down.

Fatigue will be measured using the School of Aerospace Medicine (SAM) fatigue scale. This scale ranges from one to seven as follows:

1 = Fully alert, wide awake, very peppy

- 2 = Very lively, responsive, not at peak
- 3 = Okay, somewhat fresh
- 4 = A little tired, less than fresh
- 5 = Moderately let down
- 6 = Extremely tired
- 7 = Completely exhausted, unable to function

The case definition for fatigue will be any rating of 4 or above. These will be graded as mild (rating of 4), moderate (rating of 5) and severe (rating of 6 or 7).

No physiologic measurements will be taken during this study.

*Ethical considerations:* Strict confidentiality will be maintained by all. All questionnaires will be sealed by the study subject (pilot) immediately after completion of post-mission questionnaire. These will be then returned to the author. Personal identifiers (name, SSAN etc.) will not be used at any time. Study as designed will have no impact on cockpit resource management, mission completion, mission safety or pilot health.

*Data Collection, Collation, and Tabulation:* Sealed raw data results will be returned to the author for collation and tabulation.

*Data Display:* Contingency tables and bar charts would be the most appropriate way to display the data.

*Data Analysis Plan:* The data gathered will be ordinal, in the form of percentages and proportions. The incidence of pilot fatigue will be reported as the number of pilots experiencing episodes of fatigue per mission flown. The association of the independent variables with fatigue will be analyzed by t-test methodology

a. List of Equipment and Facilities:

i. Pre and post-mission questionnaires as well as mission logs will be provided for each subject to record data as outlined above. An opaque envelope will be provided as well.

b. Participating subjects:

The specific study group will include all pilots belonging to the 68<sup>th</sup> Airlift Squadron (AS) stationed at Kelly AFB, TX.

i. Inclusion Criteria. All C-5 pilots belonging to the 68<sup>th</sup> Airlift Squadron (AS) stationed at Kelly AFB, TX.

ii. Exclusion Criteria. Those not meeting inclusion criteria as above.

iii. Screening Evaluation. Volunteer subjects will be briefed at the squadron safety meeting. No other screening measures to be done above those performed by the 68<sup>th</sup> Aeromedical Squadron IAW AFI 48-123.

iv. Efficacy Measures. The efficacy measure is the degree of subjective fatigue noted on the mission log.

v. Informed Consent. The subject will read and sign the informed consent statement (Appendix 1).

vi. Masking. None required.

vii. Experimental Set and Subject Instructions. The subjects will be told that the purpose of the experiment is to evaluate the incidence of subjective aircrew fatigue in the operational setting.

viii. Termination. Subjects have the right to withdraw from the study at any time, and the investigator also has the right to withdraw subjects from the study for reasonable cause. Subjects who with-draw consent prior to a session simply become un-available.

ix. Administrative Responsibilities. Study data will be recorded by the subjects and collected by the investigator at Brooks AFB.

10. MEDICAL RISK ANALYSIS: Study as designed will have no impact on cockpit resource management, mission completion, mission safety or pilot health.

## Appendix 11: Committee for the Protection of Human Subjects Request

### The University of Texas Health Science Center at Houston SCHOOL OF PUBLIC HEALTH

#### Student Proposal Cover Sheet

\*\*\*\*\*  
Title: Incidence of USAF Aircrew Fatigue in the Operational Setting  
Principal Investigator: Karl E Lee, Lt Col, USAF, MC, FS  
Degree Program: Masters of Public Health  
Discipline/Module: N/A  
Phone Number: Day: 210-862-1717 Evening: 210-479-7254  
Funding Source: N/A  
\*\*\*\*\*

#### Description

Though subjective fatigue measures have been utilized in assessing aircrew fatigue, none have attempted to establish its overall incidence in the USAF flying community. The purpose of this study will be to investigate the incidence of subjective fatigue in the USAF operational environment. The specific research question is: What is the incidence of subjective aircrew fatigue in the USAF operational environment?

This study will look specifically at those pilots who regularly fly long transport missions. The specific study group will include all pilots belonging to the 68<sup>TH</sup> Airlift Squadron (AS) stationed at Kelly AFB, TX. This squadron has approximately 60 pilots and flies the C-5 Galaxy transport aircraft exclusively. Pre and post-mission questionnaires will be completed prior to and at mission completion respectively. Throughout the mission, the study subjects will complete a mission log (attachment 3).

This mission log will track type of activity, serial fatigue rating, and place of sleep. Subjective fatigue will be rated starting at mission onset, every four hours throughout the mission and at mission completion, that is at time of engine shut down. Fatigue will be measured using the School of Aerospace Medicine (SAM) fatigue scale.

No physiologic measurements will be taken during this study.

\*\*\*\*\*

This research project is not underway and will not begin until approval has been received:

Karl E Lee, LtCol, USAF, MC, FS \_\_\_\_\_  
Principal Investigator Date

This project has received review for scientific merit:

John Herbold, D.V.M., Ph.D. \_\_\_\_\_  
Advisor Date

Jimmy Perkins, Ph.D. \_\_\_\_\_  
Member Date

\_\_\_\_\_  
Dean Date

The University of Texas Health Science Center at Houston  
School of Public Health

CPHS Form - Student Proposal

TITLE OF PROPOSAL: Incidence of USAF Aircrew Fatigue in the  
Operational Setting

PRINCIPAL INVESTIGATOR: Karl E Lee, Lt Col, USAF, MC, FS  
UTHSC/SA School of Public Health

DATE SUBMITTED: 20 Jan 1998

---

Copies of the following materials should be included with the proposal:

Informed Consent Documents and Translations (see instructions following the last page of the CPHS Form).

Letter of Approval/Cooperation (to use records or facilities or to recruit subjects; also copies of prior human subjects approval).

Questionnaires, Surveys, Data Collection Forms and Translations

List of Attachments Following Masters Thesis Proposal:

- Attachment 1 Pre-mission Questionnaire.
- Attachment 2 Post-mission Questionnaire.
- Attachment 3 Mission Log.
- Attachment 4 Experimental Protocol (Submitted the ACHE, Brooks AFB).
- Attachment 5 Letter from Dr French granting permission to use data collected during study.
- Attachment 6 Informed Consent Document.
- Attachment 7 Letter from Colonel O'Toole, 68<sup>th</sup> Medical Squadron Commander, 433<sup>rd</sup> Airlift Wing, USAF Reserves that grants permission to do study (note: this may not be enclosed due to clerical delays).

SUBJECTS  
STUDY1. AGE: 25-50 SEX: M & F NUMBERS: 60 TotalPOPULATION:SOURCE OF SUBJECT POOL OR RECORDS:

The specific study group will include all pilots belonging to the 68<sup>th</sup> Airlift Squadron (AS) stationed at Kelly AFB, TX. This squadron has approximately 60 pilots and flies the C-5 Galaxy transport aircraft exclusively.

INCLUSION CHARACTERISTICS:

The specific study group will include all pilots belonging to the 68<sup>th</sup> Airlift Squadron (AS) stationed at Kelly AFB, TX.

EXCLUSION CHARACTERISTICS:

Individuals not pilots and not members of the 68<sup>th</sup> Airlift Squadron (AS) stationed at Kelly AFB, TX.

PROCEDURES USED TO DETERMINE IF SUBJECTS FIT CHARACTERISTICS:

All subjects will be members of the 68<sup>th</sup> Airlift Squadron (AS) stationed at Kelly AFB, TX.

CONTROLS

A CONTROL GROUP WILL NOT BE USED IN THE STUDY

STUDY DEALS ONLY WITH DATA/RECORD/SPECIMEN ANALYSIS

2.   X   THIS STUDY DEALS ONLY WITH ANALYSIS OF DATA/  
YES NO RECORDS/SPECIMENS        WHICH HAVE ALREADY BEEN  
COLLECTED        WILL BE COLLECTED FOR PURPOSES  
OTHER THAN THIS RESEARCH.

  X   IDENTIFYING INFORMATION IS CODED AND P.I. HAS  
YES NO NO NEED TO ASCERTAIN IDENTITIES.

COMMENTS:

No personal identifiers will be used at any time during this study.

SPECIAL POPULATIONS

3. NAME AND JUSTIFY THE USE OF ANY SPECIAL POPULATION  
(EG SEVERE ACUTE/CHRONIC MENTAL OR PHYSICAL ILLNESS,  
CHILDREN OR THE AGED, PREGNANT WOMEN, THE  
INSTITUTIONALIZED, ETC.):  
N/A - No special populations to be used.

RECRUITMENT

4. DETAIL HOW SUBJECTS/CONTROLS WILL BE NOTIFIED OF THE  
STUDY AND INVITED TO PARTICIPATE:  
Official briefing fully describing the study will be  
presented to the 68<sup>th</sup> Airlift Squadron (AS) at the next  
available safety meeting.

INFORMED 5.   X   INFORMED CONSENT WILL BE OBTAINED  
 CONSENT YES NO  
 COMMENTS: (INCLUDE WHY CONSENT/WRITTEN CONSENT WILL  
 NOT BE OBTAINED)  
 N/A

WHO WILL 6. CONSENT WILL BE GIVEN BY   X   THE SUBJECT/CONTROL.  
 GIVE CONSENT

ADULTS NOT 7.          X   THERE IS A POSSIBILITY THAT AN ADULT SUBJECT/  
 ABLE TO FULLY YES NO CONTROL WILL BE CONSIDERED FOR THIS RESEARCH  
 UNDERSTAND WHO WHILE LEGALLY COMPETENT TO CONSENT, IS NOT  
 WHAT IS BEING ABEL TO COMPREHEND THE FULL EXTENT OF WHAT IS  
 REQUESTED BEING REQUESTED.

COMMENT: (INCLUDE HOW SUCH INDIVIDUALS WILL BE  
 IDENTIFIED AND WHAT PRECAUTIONS WILL BE TAKEN TO  
 ENSURE THAT THEIR RIGHTS ARE NOT VIOLATED)  
 N/A.

TRANSLA- 8.          X   TRANSLATIONS WILL BE MADE INTO THE FOLLOWING  
 TIONS YES NO LANGUAGE(S) FOR THOSE NOT CONVERSANT IN  
 ENGLISH:

CONFIDEN- 9.          X   P.I. WILL SEE IDENTIFIERS (NAME, HOSPITAL  
 TIALITY YES NO NUMBER, ETC.)  
         X   P.I. WILL RECORD IDENTIFIERS.  
 YES NO  
  X   RECORD ONLY BY STUDY CODE NUMBER.  
 YES NO

## COMMENTS:

Each subject will complete previously numbered forms -  
 no personal identifiers to be used.

10. DESCRIBE THE METHODS USED TO ASSURE THE  
 CONFIDENTIALITY/ANONYMITY OF SUBJECTS/CONTROLS:  
 Strict confidentiality will be maintained by all. All  
 questionnaires will be sealed by the study subject  
 (pilot) immediately after completion of post-mission  
 questionnaire. These will be then returned to the  
 author. Personal identifiers (name, SSAN etc.) will  
 not be used at any time.

RISKS 11. WHAT ARE THE RISKS (PHYSICAL, PSYCHOLOGICAL, SOCIAL,  
 LEGAL OR OTHER) THAT COULD ARISE FROM SUBJECT/CONTROL  
 PARTICIPATION. ESTIMATE THE LIKELIHOOD OF OCCURRENCE:  
 Study as designed will have no impact on cockpit  
 resource management, mission completion, mission  
 safety or pilot health. No significant risks  
 foreseen.



SAFEGUARDS 12. WHAT SAFEGUARDS WILL BE USED TO MINIMIZE OR PROTECT AGAINST RISK?

N/A

CARE/COM-  
PENSATION  
FOR INJURY

13. YES X NO ARRANGEMENTS HAVE BEEN MADE TO PROVIDE FREE CARE OR COMPENSATION IF INJURY IS SUSTAINED BY SUBJECTS/CONTROLS AS A RESULT OF PARTICIPATION IN THIS RESEARCH.

Note: All subjects are members of the USAF Reserves. Medical care and compensation provided be USAF medical system.

FINANCIAL  
BENEFIT

14. YES X NO BY ENTERING THIS STUDY, SUBJECTS/CONTROLS WILL RECEIVE:  
       CARE        DRUGS        DEVICES AT NO COST.

OTHER  
BENEFITS

15. WHAT ARE THE BENEFITS (DIRECT OR INDIRECT) TO BE DERIVED BY BENEFITS SUBJECTS, CONTROLS, OR SOCIETY AT LARGE:

It is well documented that aircrew fatigue occurs in the operation setting - however, its incidence has not been adequately studied in the USAF operational environment. The initial benefit of this study will be to quantify the incidence of subjective fatigue in an USAF C-5 transport squadron during sustained operations missions.

It is also well documented that fatigue, an over-reaching human factor, is associated with decrements in aircrew performance that can lead to human error. In that human error is implicated in 71% of recent USAF mishaps, there is a considerable amount to gain from quantifying fatigue in the operational setting. This study will set the stage for future studies to assess fatigue's impact on performance, and the effect of implementing specific countermeasures to lesson its adverse impact.

TIME SPENT 16. WHAT IS THE AMOUNT OF TIME WHICH SUBJECTS/CONTROLS WILL BE REQUIRED TO SPEND IN ORDER TO PARTICIPATE:

Minimal time expenditure above regular duty schedules. Estimate maximum of five minutes to complete the pre and post mission questionnaires and no more than a minute for each notation made on the mission log (maximum of 5 notations).

COSTS TO  
SUBJECTS

17. YES X NO BY ENTERING THIS STUDY, SUBJECTS/CONTROLS WILL INCUR        COSTS FOR TREATMENT        OTHER COST WHICH WOULD NOT OTHERWISE BE INCURRED.

- REIMBURSE- 18. YES X NO REIMBURSEMENT WILL BE MADE TO SUBJECTS /  
MENT CONTROLS
- SIGNIFICANT 19. YES X NO DURING THE COURSE OF THIS STUDY, NEW FINDINGS  
NEW FINDINGS MAY BECOME APPARENT WHICH IF KNOWN BY  
SUBJECTS/CONTROLS MIGHT INFLUENCE CONTINUED  
PARTICIPATION.
- REPORTING 20. X YES NO SUBJECTS/CONTROLS WILL BE GIVEN A SUMMARY OF  
THE RESULTS RESULTS.
21. X YES NO SUBJECTS/CONTROLS WILL BE TOLD OF PROBLEMS  
ISOLATED AND SUGGESTIONS MADE FOR FURTHER  
CARE.
23. X YES NO PROBLEMS ISOLATED WILL BE TOLD TO A PHYSICIAN,  
AGENCY, PARENT, EMPLOYER, ETC.

## COMMENTS:

Study results to be published.

- OTHER USE 23. YES X NO IN ADDITION TO OTHER ASPECTS OF THE STUDY, THE  
FOLLOWING WILL BE USED:        MEDICAL RECORDS  
       AGENCY RECORDS        TEST RESULTS X DATA.

THIS MATERIAL WILL BE OBTAINED FROM:

Data collected during the study will be  
analyzed. No other data to be used.

- QUESTION- 24. YES X NO PERSONALLY SENSITIVE QUESTIONS WILL BE ASKED.  
NAIRES/  
INTERVIEWS/  
TESTS/RATING  
SCALES COMMENTS:

25. LIST THE STUDY INSTRUMENTS (E.G. QUESTIONNAIRES) TO BE  
USED AND COMMENT UPON THEIR RELIABILITY/VALIDITY:  
Pre-mission questionnaire - valid (Attachment 1)  
Post-mission questionnaire - valid (Attachment 2)  
Mission log - valid (Attachment 3)

- USE OF 26. YES X NO TISSUES/FLUIDS WILL BE USED IN THIS STUDY.  
TISSUES OR  
FLUIDS

- DRUGS 27. YES X NO DRUGS WILL BE USED IN THIS STUDY. NAME(S) OF  
DRUGS: N/A.

MEDICAL  
DEVICES \*DEFINITION: ANY ITEM FOR A MEDICAL PURPOSE WHICH  
DOES NOT RELY ON CHEMICAL ACTION TO ACHIEVE ITS

INTENDED EFFECT. INCLUDES IN VITRO DIAGNOSTIC TESTS AND COMPUTER SOFTWARE.

28. YES X NO MEDICAL DEVICES WILL BE USED IN THIS STUDY.  
NAME(S) OF DEVICE(S): N/A.
- DIAGNOSTIC TESTS 29. YES X NO DIAGNOSTIC TESTS WILL BE USED IN THIS STUDY.
- RADIATION 30. YES X NO SUBJECTS WILL BE EXPOSED TO        RADIOACTIVE  
DRUGS OR ISOTOPES        IONIZING RADIATION.
- LETTERS OF APPROVAL/  
COOPERATION 31. YES X NO A LETTER OF APPROVAL HAS BEEN/WILL BE  
REQUESTED FROM HERMANN HOSPITAL.
32. YES X NO LIST OTHER LETTERS WHICH HAVE BEEN/WILL BE  
REQUESTED.  
FOR EACH LETTER, STATE: 1) THE TYPE OF  
APPROVAL/COOPERATION REQUESTED; 2) THE  
SPECIFIC INSTITUTION, DEPARTMENT, AGENCY  
INDIVIDUAL, IRB, ETC.; AND 3) WHETHER THE  
LETTER IS ATTACHED, IS FORTHCOMING, OR WILL BE  
REQUESTED:

A proposal for this study has been submitted to the Advisory Committee for Human Experimentation (ACHE) at Brooks AFB, TX and is awaiting approval (Attachment 4). This study will be accomplished in conjunction with the Crew Systems Directorate, Sustained Operations Branch, Armstrong Laboratory at Brooks AFB, TX. Author will be working directly with research physiologist, Jonathan French, Ph.D. To facilitate the process at Brooks AFB, Dr French is listed as principle investigator on the proposal submitted to the ACHE. Approval letter forthcoming pending review, which will take place on 3 February. Permission for use of all data has been granted by Dr French (Attachment 5). Verbal approval has been granted by Colonel O'Toole, Medical Squadron Commander, 68<sup>th</sup> Airlift Squadron, Kelly AFB, TX. This approval granted after consultation with both the 68<sup>th</sup> Airlift Operations Squadron Commander and the 433<sup>rd</sup> Airlift Wing Commander. Written confirmation requested and is pending (Attachment 6).

MEMORANDUM FOR RECORD

16 Jan 98

FROM: AL/CFTO  
2504 Gillingham Dr Ste 25  
Brooks AFB TX 78235-5104

TO: Anne Dougherty, MD, Chair  
Committee for the Protection of Human Subjects  
University of Texas, School of Public Health

SUBJECT: Incidence of USAF Aircrew Fatigue in Operational Setting Study  
Permission for Lt Col Karl Lee to use data set

1. Be advised that Lt Col Karl Lee is currently participating with the Crew Systems Directorate, Sustained Operations Branch in a research study to determine the incidence of aircrew fatigue in the operational setting. To facilitate this process with the United States Air Force, I am on record officially at Brooks AFB as the principle investigator with Lt Col Lee as the co-principal investigator.
2. Lt Col Karl Lee has permission to use/analyze all data collected as outlined in his detailed masters' thesis proposal that I have reviewed and which has been submitted to you. The thesis proposal is entitled "Incidence of USAF Aircrew Fatigue in Operational Setting." No personal identifiers will be used in this study. The study proposal has been formally submitted to the Advisory Committee for Human Experimentation here at Brooks AFB and will be reviewed the first week of February. I foresee no problem with its approval.
3. If you have any questions, please feel free to call me at 210-536-8140.

Sincerely,



Jonathan French, Ph.D.  
Research Physiologist

MEMORANDUM FOR RECORD

3 Feb 98

FROM: Karl E Lee, Lt Col, USAF, MC, FS  
3534 Hunters Glade  
San Antonio, TX 78230

TO: Committee for the Protection of Human Subjects  
ATTN: Kathleen Cook

SUBJECT: Request to expedite CPHS review of masters thesis proposal titled  
"Incidence of USAF Air Crew Fatigue in the Operational Setting"

1. Please consider expediting the review of my masters thesis proposal titled "Incidence of USAF Air Crew Fatigue in the Operational Setting".
2. As an active duty officer in the United States Air Force and resident in Aerospace Medicine, I must complete my Masters work in a somewhat limited period of time (most commonly two semesters). I plan to graduate in May of this year, which requires that I complete my masters thesis by 27 April 1998.
3. I will be doing the first study in the USAF operational environment that looks specifically at the incidence of aircrew fatigue. I am quite excited about this project and have worked very hard to put it all together in the midst of my other studies. I have been most fortunate to obtain the approval of the commanders of the 433<sup>rd</sup> Air Lift Wing and 68<sup>th</sup> Air Lift Squadron at Kelly Air Force Base. Study subjects will be exclusively the pilot members of the 68<sup>th</sup> Air Lift Squadron. I am scheduled to brief the entire squadron on 8 February 1998 at the time of their monthly safety meeting.
4. As you can see, I have a fortuitous window of opportunity in which to achieve my goals. I stand ready to start collecting data - all I need at this point is your permission to initiate the study. The Advisory Committee for Human Experimentation at Brooks AFB is to review my proposal on 3 February, 1998 - I foresee their full approval for the study as designed.
5. I truly appreciate your consideration in expediting the review of my masters thesis proposal. I am excited to get started.

Sincerely,

KARL E. LEE  
Lieutenant Colonel, USAF, MC, FS  
210-479-7254 or 210-862-1717

MEMORANDUM FOR RECORD

3 Feb 98

FROM: Karl E Lee, Lt Col, USAF, MC, FS  
3534 Hunters Glade  
San Antonio, TX 78230

TO: Committee for the Protection of Human Subjects  
ATTN: Kathleen Cook

SUBJECT: Additional clarification for masters thesis proposal titled "Incidence of  
USAF Air Crew Fatigue in the Operational Setting"

1. Please be advised of the following clarifications:
  - a. At no time have I been or will I be in a position of supervising any of the individuals assigned to the 68<sup>th</sup> Airlift Squadron. Only members of this squadron that will participate as study subjects.
  - b. Members of the 68<sup>th</sup> Airlift Squadron are under no pressure to participate as study subjects. Participation will be entirely voluntary.
  - c. Absolute confidentiality will be maintained at all times. At no time during this study will personal identifiers be used. The tools used to collect data (pre and postmission questionnaires and mission log) will be pre-numbered and enclosed in individual envelopes marked with the same number. These envelopes will be sealed at the completion of the mission by the study subject and returned to a secure collection site in the squadron's mission briefing room located at Kelly AFB, San Antonio, TX. I will personally collect all envelopes on a weekly basis from that site.
  - d. The entire 68<sup>th</sup> Airlift Squadron will be briefed in detail as to the purpose of this study and its methodology. This briefing is scheduled to take place on 8 February, 1998 coincident with the Squadron's safety briefing.
2. I hope the above serves to clarify the issues discussed on 30 January 1998. I do appreciate your assistance in facilitating the review of my masters thesis proposal.  
Please do not hesitate to call me if you have any further questions or concerns.

Sincerely,

KARL E. LEE  
Lieutenant Colonel, USAF, MC, FS  
210-479-7254 or 210-862-1717

Attachment(s):

- (1.) MFR to expedite review.
- (2.) Letter of Information
- (2.) Power Point Briefing Presentation (Script)

## BIBLIOGRAPHY

1. Moore RY (1997): Circadian rhythms: basic neurobiology and clinical applications. *Annual Review of Medicine*. 48:253-266.
2. Ferrer CF Jr, Bisson RU, French J (1995): Circadian rhythm desynchronization in military deployments: a review of current strategies. *Aviation Space & Environmental Medicine*. 66(6):571-578.
3. Gander PH, Nguyen D, Rosekind MR, Connell LJ (1993): Age, circadian rhythms, and sleep loss in flight crews. *Aviation Space & Environmental Medicine*. 64(3):189-195.
4. Stoner JD (1996): Aircrew fatigue monitoring during sustained flight operations from Souda Bay, Crete, Greece. *Aviation Space & Environmental Medicine*. 67(9):863-866.
5. Belland KM, Bissell C (1994): A subjective study of fatigue during Navy flight operations over Iraq: Operation Southern Watch. *Aviation Space & Environmental Medicine*. 65(6):557-561.
6. Shiota M, Sudou M, Ohshima M (1996): Using outdoor exercise to decrease jet lag in airline crewmembers. *Aviation Space & Environmental Medicine*. 67(12):1155-1160.
7. French J, Bisson RU, Neville KJ, Mitcha J, Storm WF (1994): Crew fatigue during simulated, long duration B-1B bomber missions. *Aviation Space & Environmental Medicine*. 65(5):1-6.
8. Bisson RU, Lyons TJ, Hatsel C (1993): Aircrew fatigue during Desert Shield C-5 transport operations. *Aviation Space & Environmental Medicine*. 64(9):848-853.
9. Rosekind MR, Gander PH, Gregory KB, Smith RM, Miller DL, Oyung R, Webbon LL, Johnson JM (1996): Managing fatigue in operational settings 2: an integrated approach. *Behavioral Medicine*. 21(4):166-170.
10. Rosekind MR, Gander PH, Gregory KB, Smith RM, Miller DL, Oyung R, Webbon LL, Johnson JM (1996): Managing fatigue in operational settings. 1: physiological considerations and countermeasures. *Behavioral Medicine*. 21(4):157-165.
11. Costa G (1997): The problem: shiftwork. *Chronobiology International*. 14(2):89-98.

- 12 Rosekind MR, Gander PH, Miller DL, Gregory KB, Smith RM, Weldon KJ, Co EL, McNally KL, Lebacqz JV (1994): Fatigue in operational settings: examples from the aviation environment. *Human Factors*. 36(2):327-338.
- 13 Neville KJ, Bisson RU, French J, Boll PA, Storm WF (1994): Subjective fatigue of C-141 aircrews during Operation Desert Storm. *Human Factors*. 36(2):339-349.
14. Murphy PJ, Campbell SS (1996): Physiology of the circadian system in animals and humans. *Journal of Clinical Neurophysiology*. 13(1):2-16.
- 15 Richardson GS, Malin HV (1996): Circadian rhythm sleep disorders: pathophysiology and treatment. *Journal of Clinical Neurophysiology*. 13(1):17-31.
- 16 Wagner DR (1996): Disorders of the circadian sleep-wake cycle. *Neurologic Clinics*. 14(3):651-670.
- 17 General Accounting Office, Washington D.C., National Security and International Affairs Division, Military Aircraft Safety: Significant Improvements Since 1975. Washington, GPO, February 1996.
- 18 Advisory Group for Aerospace Research and Development, Aircraft Accidents: Trends in Aerospace Medical Investigation Techniques. Papers Presented at the Aerospace Medical Panel Symposium, 1996.
- 19 Napier JH, *Air Force Officers Guide 30<sup>th</sup> Ed*, Harrisburg PA, Stackpole Books, 1995.
- 20 Air Force Instruction 11-206, General Flight Rules, Department of the Air Force, Washington, GPO, 25 July 1994.
- 21 Carskadon MA, Dement WC (1989): Normal human sleep: an overview. In M.H. Kryger, T. Roth, and W.C. Dement (Eds), *Principles and Practice of Sleep Medicine*. Philadelphia PA, W.B. Saunders, 1989.
22. Moore-Ede MC, Czeisler CA, Richardson GS (1983): Circadian timekeeping in health and disease part 1: basic properties of circadian pacemakers. *New England J of Med*. 309(8):469-476.
23. Lauber JK, Kayten PJ (1988): Sleepiness, circadian dysrhythmia, and fatigue in transportation system accidents. *Sleep*. 11(6):503-512.
24. Mitler MM, Carskadon MA, Czeisler CA, Dement WC, Dinges DF, Graeber RC (1988): Catastrophes, sleep, and public policy: consensus report. *Sleep*. 11(1):100-109.



## VITA

Karl Edward Lee was born in Newark, Ohio on April 1, 1954, the fourth of five sons to Norman and Bonnie Lee. Graduating from Newark Catholic High School in 1972, he attended Wittenberg University in Springfield, Ohio. Earning a BA degree with a major in Biology, he attended the Chicago College of Osteopathic Medicine in Chicago, Illinois. He was accepted into the US Army's Health Professions Scholarship Program (HPSP), commissioned as an officer, and was a Fellow in Biochemistry. Graduating in June of 1981, he was accepted into Eisenhower Army Medical Center's Family Practice Residency at Fort Gordon, Georgia where he served as Chief Resident. Attaining Board Certification in 1984, he was transferred to Redstone Arsenal in Huntsville, Alabama, served out his active duty commitment, and was honorably discharged in November 1987. He practiced family medicine in rural Ohio for five years prior to returning to the Armed Services. Stationed at Wright-Patterson AFB in Dayton, Ohio he spent the first two years as Chief of the Medical Center's Primary Care Service. With a growing interest in operational and aviation medicine, he attended the Aerospace Medicine Primary Course in the spring of 1995. By June of that same year he obtained transfer to the Aerospace Medicine Squadron and by August of that same year was Chief of Hospital Services, US Hospital Zagreb, Croatia in support of the UN Operation Provide Promise. He was accepted into the Residency in Aerospace Medicine in the fall of 1996.

Lt Col Lee and his lovely wife of 21+ years, Devon, are truly blessed to be the parents of three wonderful children; Kristina, Kathryn and Nathan.

This Thesis was typed by the author. Address: 3534 Hunters Glade, SA TX 78230