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A STUDY OF FATIGUE AND PERFORMANCE CONSIDERATIONS IN AIR MOBILITY COMMAND CARGO AIRCREWS FLYING TRANSATLANTIC MISSIONS

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A STUDY OF FATIGUE AND PERFORMANCE CONSIDERATIONS IN AIR MOBILITY COMMAND CARGO AIRCREWS FLYING TRANSATLANTIC MISSIONS

By

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THESIS

Presented to the Faculty of The University of Texas

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in Partial Fulfillment

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A STUDY OF FATIGUE AND PERFORMANCE CONSIDERATIONS IN AIR MOBILITY COMMAND CARGO AIRCREWS FLYING TRANSATLANTIC MISSIONS

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U.S. Air Force Air Mobility Command (AMC) cargo aircrews fly throughout the world in support of the United States national interest. There are not specific shifts which the aircrews work in accomplishing airlift missions. Missions departing from the East Coast for a transatlantic location may depart at any hour of the day or night depending on scheduling and operational need. Effects of subjective fatigue have been studied in surge operations like Desert Shield and Desert Storm and prolonged simulated bomber missions. The cargo mission profile which places the aircrews at increased risk of fatigue related decrements in performance have not been fully studied in "routine" missions.

This descriptive study used data from the Air Mobility Performance Analysis System (AMPAS) on compact disc to review transatlantic mission profiles for three types of AMC cargo aircraft from either Charleston AFB, SC, or Dover AFB, DE. A total of 170 missions reviewed met the criteria for transatlantic missions, 72 C-141, 76 C-5, and

170 missions reviewed met the criteria for transatlantic missions, 72 C-141, 76 C-5, and 22 C-17. The average mission duration was 10.64 hours, with the C-141 having statistically longer mission duration than the C-5. The primary factor in longer mission duration was the number of missions with at least one intermediate stop. The C-5 missions studied had significantly more missions without intermediate stops than those of C-141 or C-17. Forty-one missions (24%) landed during the predicted time of the crew circadian nadir. Of these, 21 (12.4%) were hypothesized to be at highest risk for fatigue related decrements in performance. These were the missions departing in the 1600-2000 time frame with landing at the transatlantic destination at the crew "body clock time" of 0200-0600.

There were several major study limitations. The small number of C-17 missions limited statistical comparison. It was not possible from the data available to determine if the missions had an augmented crew, or if naps were used to reduce fatigue effects. The full duty day is far longer than the mission time calculated, but could not be ascertained in this study. Certain assumptions about crew sleep habits were made in the hypothesis of the highest risk missions. A follow on study will be needed to objectively measure fatigue effects in those missions felt to be at highest risk.

Continued efforts at fatigue countermeasures education and improved scheduling practices is warranted now. Evaluating fatigue effects in the C-17 with smaller basic crew than the C-5 or C-141, and longer crew duty day than comparable civilian aircraft should be a high priority for AMC.

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"My mind clicks on and off.....I try letting one eyelid close at a time while I prop the other open with my will. But the effort's too much. Sleep is winning. My whole body argues dully that nothing, nothing life can attain, is quite so desirable as sleep. My mind is losing resolution and control."

C.A. Lindbergh, *The Spirit of Saint Louis*
(Scribners, New York, 1953)

INTRODUCTION

The U.S. Air Force Air Mobility Command (AMC) is responsible for movement of supplies and personnel, air refueling operations and air evacuation operations throughout the world in support of the United States' national interest. Continued peacekeeping and humanitarian missions require a robust "air-bridge" for deployment and resupply of US and multinational forces world-wide. AMC cargo aircrews flying missions departing from US bases for transatlantic destinations frequently endure long duty days. Take-offs from the home base often disrupt normal sleep patterns and landings at the destination may occur during the circadian nadir. AMC aircrews differ from ordinary shift-workers in that they fly irregular hours without time to adapt to a routine overnight schedule. To this disruption in normal sleep patterns transatlantic missions add the additional factor of a 5-6 hour phase shift in the normal circadian cycle. As noted by Luce, those workers not placed on stable shifts "suffer" significantly more than regular shift workers (29). They experience greater disruption in body rhythms and the associated physiologic and psychologic effects (29). Aircrew sleep cycles have generally not been considered when scheduling these "routine" missions. The recently released "Scientific Review of Air Mobility Command Crew Rest

Policy and Fatigue Issues" demonstrates the importance of reevaluation of current policies and the need for continued studies (53). This study of the scheduling of transatlantic missions will hopefully add to the current knowledge leading to policy decisions based on facts.

PURPOSE

The purpose of this study is to review mission characteristics which place the aircrew at increased risk of fatigue from prolonged periods awake and accumulated sleep debt and circadian desynchronization. It was theorized based on the review of literature, and personal experience of the author, that departing home base between 0200 and 0600 place the crews at increased risk of beginning a long and demanding mission with a sleep debt, while departing between 1600 and 2000 increases continuous time awake with a landing more likely during the circadian nadir. This report is intended to lead to a follow-on study of crews thought to be at highest risk. The review will include aircraft schedules from 2 bases, Charleston AFB, South Carolina and Dover AFB, Delaware, flying 3 types of aircraft, C-5, C-141, and C-17. The C-17 is the newest jet engine cargo aircraft in the Air Force inventory. Its highly automated instrumentation has allowed for the elimination of the Navigator and Flight Engineer positions. Although the smaller crew size is now common in newer commercial aircraft, the C-17 is the first large military cargo aircraft designed to allow a smaller basic crew. It is unclear how the introduction of more highly automated aircraft like the C-17, with smaller aircrews, will affect crew performance on these long range missions.

BACKGROUND AND LITERATURE REVIEW

The safety record for AMC cargo flights has been extremely good, but the potential for fatigue-related incidents remains significant (53). The "Scientific Review" noted that "statistics gathered by the Air Force Safety Center indicate that sleep loss and circadian disruption were often implicated in the 96 Class A fatigue-related mishaps for the years 1972-1995 (53). Circadian rhythm desynchrony was a factor in 15.6% of 77 operation-related mishaps reviewed (53). The NASA Aviation Safety Reporting System (ASRS), which receives confidential reports from civilian and military aircrews about aircraft incidents and accidents, reports that 21% of the reported incidents are fatigue-related. (42).

It is now well accepted that sleep provides a vital function, and that significant disruption in normal sleep produces fatigue (29,30,51). Fatigue is difficult to define but involves a subjective feeling of tiredness, possibly impaired psychomotor performance, and momentary lapses of attention (37). Multiple factors contribute to the extent to which fatigue causes impairment. The duration of sleep loss, the pattern of loss over time, and the phase in the circadian cycle are primary factors. Psychological factors (e.g., motivation), age and physical factors such as noise, vibration, heat, and cold affect the degree to which fatigue impacts operational performance (37,49,52). Significant symptoms of fatigue may include slowed reaction time, reduced vigilance, poor communication, poor decision making and others, any of which may contribute to accidents (46). The increasing

recognition of fatigue as a contributor to adverse events has stimulated interest in countermeasures to reduce risk (44).

Fatigue is now considered during accident safety investigations performed by the National Transportation Safety Board (NTSB) and the Federal Aviation Administration (FAA). In a 1993 DC-8 crash at Guantanamo Bay, Cuba the NTSB found "the probable cause of this accident were the impaired judgment, decision-making, and flying abilities of the captain and flight crew due to the effects of fatigue" (34). Recommendations to the FAA led to revisions of the Code of Federal Regulations (CFR), and to improved training and company policy changes at the responsible carrier, American International Airways, Inc (34).

The role of fatigue in other transportation industries has also received more attention. In 1990 the NTSB completed a study of 182 heavy truck accidents that were fatal to the truckdriver. The primary purpose of the study was to investigate the role of alcohol and drugs, but the most frequently cited probable cause (31%) was fatigue (33). The Fatal Accident Reporting System (FARS) data maintained by the National Highway Traffic Safety Administration (NHTSA), found that in 1993 there were over 3,300 heavy trucks involved in accidents in which 3,783 people died (32). The NTSB (an independent agency from the NHTSA) initiated a study to further evaluate the factors involved in single vehicle heavy truck accidents. These findings were published in 1995 in: "Safety Study; Factors that Affect Fatigue in Heavy Truck Accidents, Volume 1" (32). The Board reviewed 107 heavy truck accidents from 8 non-contiguous states from September 1992

through June 1993 in which the driver survived and provided a 96 hour history. They found that "based on the determination of probable cause, 58 % of the accidents were fatigue-related. Nineteen of the 107 drivers stated that they fell asleep while driving". They determined "that the most important measure in predicting a fatigue-related accident in this sample are the duration of the last sleep period, the total hours of sleep obtained during the 24 hours prior to the accident, and split sleep patterns" (32). This study resulted in recommendations for improvements to the Federal Highway Administration Regulations and recommendations to multiple trucking professional associations. The Safety Board has also identified fatigue as a probable cause, or contributor to serious train crashes and the high profile grounding of the oil tanker, the Exxon Valdez (32).

The US Air Force and NATO have long been involved in the study of fatigue in the operational environment. The Advisory Group for Aerospace Research & Development (AGARD) has produced several benchmark publications (23,25,37). That interest continues with the increasing importance of night operations and increasing use of long range bombers and multiple refuelings of both bomber and transport aircraft placing tremendous stresses on the pilots. Bisson studied subjective fatigue ratings and observed performance of C-5 crewmembers during surge operations of Operation Desert Storm. He found that increased length of duty day, being awake late during the local night, and length of last sleep as factors most closely associated with moderate or extreme fatigue in the C-5 crewmembers flying from Europe to the Middle East and back (3). The study of subjective fatigue in C-141 aircrew by Neville demonstrated that increased fatigue was related to recent (48 h) cumulative flight and sleep history (35). He found a tendency for fatigue to

correspond with pilot error. His findings suggest that the duration of sleep may be the most important factor to control in long-duration operations (35). The association found between flight performance deviations and subjective fatigue underscores the importance of fatigue management practices whenever possible. Although different in mission profile than cargo missions, French in his study of 36 hour simulated B-1B bomber missions found that crew members maintained their local home base circadian rhythms. He noted that the quality and duration of sleep were lowest on the first of 3 consecutive missions, highlighting the need for realistic training in long duration fatigue management (14).

Circadian desynchronosis can present special problems in these long duration missions (25). People living on a regular 24 hour schedule, as are the aircrews before a mission, experience 2 periods of maximum sleepiness. These are the circadian nadirs, which occur for most people from approximately 0300-0500, and 1500 to 1700 (46). Extensive research into circadian rhythms and their effect on performance in an operational environment has been performed and reviewed by Klein and Wegman.(25). Desynchronization of human physiological rhythms after transmeridian flight has been described in a series of investigations as far back as the 1950's through the 1960's. The physiologic factors most studied are mainly for body temperature, cardiovascular and metabolic variables, and hormone and electrolyte excretion (25). Mental performance rhythms desynchronize in a similar way, with nadirs of performance varing among individuals but generally from 0200-0600 (25). Under standardized laboratory conditions, post flight studies of the effects of circadian cycle on mental performance have demonstrated the difference between the maximum and minimum score varies by from 10%

to 30% (25). Factors which have proved to be the most significant in modifying mental performance rhythms are: sleep, task variables, personality, motivation, sustained operations, physical exertion, and the relationship between the temporal organization of the body and the environment (desynchronization)(25). Deterioration of performance caused by desynchronization is generally more significant on eastbound than westbound flights. Klein and Wegman conclude that by high motivation and extra effort, circadian cycling of mental performance may be overcome, but that during the circadian nadir it will be more difficult to obtain the preflight performance levels (25). A person working through the night must maintain wakefulness when the circadian pacemaker controlling multiple hormonal functions is promoting sleep. Conversely, attempting to sleep during the day (i.e. prior to a scheduled evening mission) is difficult when the circadian pacemaker is promoting wakefulness (46).

Rosekind and Gander have studied fatigue and crew factors in commercial pilots in a variety of settings including , long-haul flight crew (43), short-haul flight crew (18), helicopter operation (16), and overnight cargo operations (17). Their work has stressed the importance of fatigue countermeasures to enhance performance. There is no "one cure" for fatigue related symptoms, but there are a series of interventions which will reduce risk. Some of these interventions include: appropriate mission scheduling including an extended crew rest period every 3 days, strategic napping to make up for accumulated sleep debt, and strategic caffeine use. The timing of layovers to coordinate with circadian cycles may improve sleep quality and duration during the layover (15). Appropriately timed bright light

exposure (9,50), melatonin use prior to sleep (40), improved diet and regular exercise, may also be useful fatigue countermeasures (46).

METHODS AND PROCEDURES

DATA COLLECTION:

This study utilized data accessible from the Air Mobility Performance Analysis System (AMPAS). The AMPAS compact disk (CD) available contained data on all AMC aircraft take-offs and landings from 1 January 1995 to June 5, 1996. This data is coded for many factors including mission number, aircraft type, base and squadron assigned, scheduled and actual take-off and landing times, flying and ground times, scheduled and actual airfield destination, and whether a delay occurred and the delay code.

Data was retrieved using Microsoft Access SQL (Structured Query Language) Queries. A separate query was built designating each aircraft type, C-141, C-17, and C-5, restricting the query to the Air Wings at each base, i.e. 437th and 315th Air Wings, to distinguish the aircraft from Charleston AFB. Specific character designations in the "Mission ID Number" were used to limit search criteria, reducing the number of missions to review which did not meet the study criteria.. The "First Mission ID Number" and "Sequence Number" fields were used in conjunction with the "Departure ICAO Code" (International Civil Aviation Organization Code designates a 4 letter identifier for all international airfields) and "Arrival ICAO Code" fields to determine transatlantic missions

for inclusion in the study. Missions departing for Greenland, Europe, or Africa were considered as transatlantic. Missions to South America and the Caribbean, as well as missions within US and the Pacific were eliminated. Consecutive missions of C-141, and C-17 aircraft stationed at Charleston AFB, South Carolina, and C-5 aircraft from Dover AFB, Delaware meeting the critera were analyzed. For C-5 and C-141 aircraft, data for 1 year, from January 1, 1995 to December 31, 1995 was used. Due to the small number of transatlantic C-17 flights during 1995, data on flights from January 1, 1995 to June 5, 1996 was included. This still provided only small numbers due to the limited number of the new aircraft available for operational missions.

Many missions departed home station with an intermediate stop and crew rest at another US base prior to the mission continuing it's transatlantic portion. The calculation for "total mission time" begins at the take-off time of the mission departing for the overseas location without an intervening crewrest. The "total mission time" was calculated by adding the flying time and the ground time for any intermediate stops. The total mission time listed in the tables does not include the average of an additional 3.5 hours to account for pre-mission preparation and planning.

Time corrections to local time are calculated to Eastern Standard Time (EST) or Eastern Daylight Time (EDT), depending on date of departure. The Eastern Time Zone matches the time zone of both home bases. The "Pilots Local Time" is used to reflect the "body-clock" time of the aircrew, and is based on EST or EDT as appropriate.

Each mission was categorized for the following variables:

- Type of Aircraft (C-5, C-141, C-17)
- Time of take-off, grouped in 4 hour blocks.(converted from Greenwich Mean Time [Z-Time] to "Local" Time).
- Landing time, Grouped by 4 hour blocks. (Z converted to "local" time based on originating base).
- Mission time. (Flying time + Ground time for any intermediate stops).
- Presence or absence of a mission delay.

DATA EVALUATION:

A total of 170 missions met the criteria for transatlantic missions flown by crews from Charleston AFB and Dover AFB and for which all needed information was present in the database. By aircraft type there were: 76 for the C-5, 72 for the C-141, and 22 for the C-17. For each aircraft type approximately 10% of the missions could not be evaluated because of incomplete information in the database or search criteria caused information to be omitted. These missions were excluded from the data calculations. There was no specific pattern to the missions with incomplete information, because they appear to be random, their exclusion should not significantly effect the calculations.

The majority of the missions evaluated were actually the first segment of a multi-day trip. Due to the search criteria selected, and characteristics of the data base, it was not possible to accurately track a majority of the missions through the continuation of the trip. Some observations on the mission continuations were possible and will be discussed later.

FINDINGS/ DISCUSSION

The total mission duration for the missions evaluated had a range from 5.4 hours to 19.7 hours. Table 1 shows the average, and mean mission duration by aircraft type. The difference between C-141 and C-5 average duration is statistically significant using the pooled student *t*-test, with a *p*-value of .026. Other comparisons were not statistically significant. Table 2 gives a further breakdown of mission durations.

	C - 141	C - 5	C - 17	Composit
AVERAGE	11.182	9.997	11.086	10.64
MEDIAN	10.95	8.25	12.2	10.0
STD DEV	3.047	3.353	2.982	3.214
TOTAL NUMBER	72	76	22	170

Table 1: Total mission duration by aircraft type

	C - 141		C - 5		C - 17		TOTAL	
DURATION	#	%	#	%	#	%	#	%
< 8 HOURS	8	11.1	32	42.1	6	27.3	46	27.1
8-9.9 HOURS	22	30.6	14	18.4	1	4.5	37	21.7
10-11.9 HOURS	14	19.4	6	7.9	3	13.7	23	13.6
12-13.9 HOURS	17	23.6	11	14.5	10	45.5	38	22.3
14-15.9 HOURS	6	8.4	10	13.2	1	4.5	17	10.0
>16 HOURS	5	6.9	3	3.9	1	4.5	19	5.3
TOTALS	72	100%	76	100%	22	100%	170	100%

Table 2: Mission Duration by time blocks

There are several items of interest from table 2 and the graphic representation seen below in figure 1. The large percentage of C-5 missions less than 8 hours is significant. This finding was due to the increased number of missions flying directly from Dover to the transatlantic destination without an intermediate stop as compared with the missions departing from Charleston. Details are as shown in Table 3.

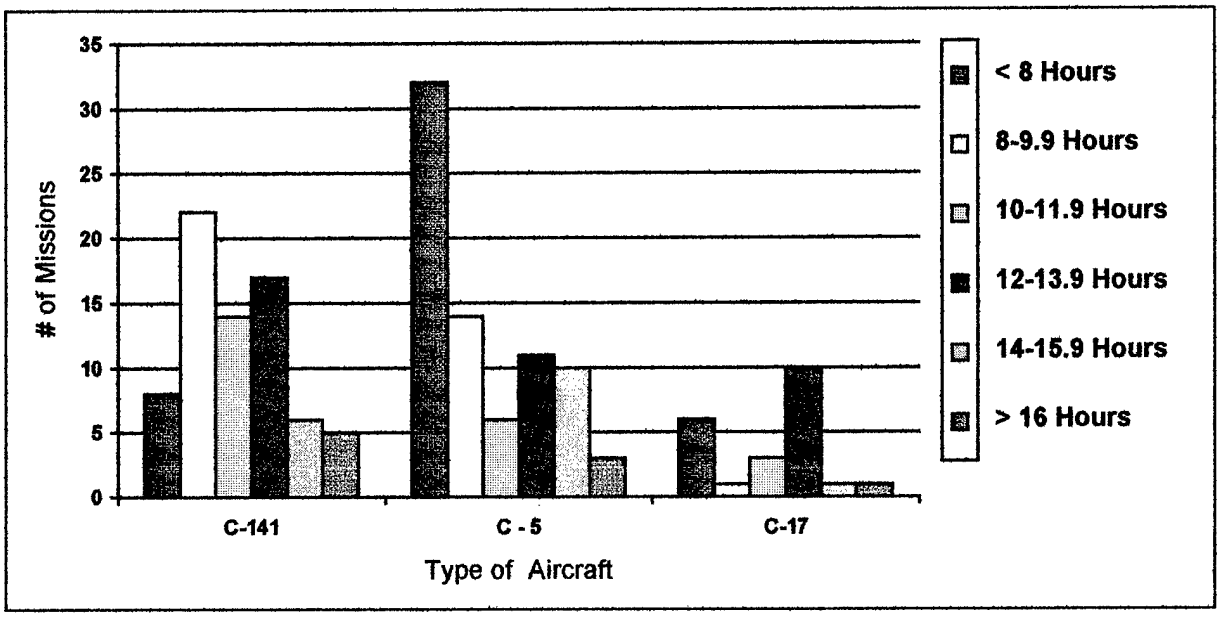

Figure 1: Number of missions by duration, with 2 hour time blocks.

	C-141		C-5		C-17	
	#	%	#	%	#	%
MISSIONS WITH STOPS	52	70.3	30	39.5	19	86.4
MEAN STOP OVER TIME	2.77 HOURS		3.79 HOURS		3.17 HOURS	
STD DEV	0.68		0.95		0.78	

Table 3: Data on intermediate stops.

The number of missions with intermediate stops and average ground times for those stops was evaluated. The C-141 had the shortest mean ground time, the C-5 the longest, and the C-17 intermediate. It is quite apparent that the number of intermediate stops is an important determinant of mission duration. The difference in mission profiles (fewer missions with intermediate stops) was the major factor in the C-5 having shorter average and median mission duration, despite having the longest average ground time. The longest missions noted in table 2 all had 2 intermediate stops. Although the number of C-17 missions was small, a large percentage of these missions were 12-14 hours in length because 19 of 22 had intermediate stops en route to the transatlantic destination.

TAKE-OFF TIME:

Table 4 list take-off times divided into 4 hour segments. The number of missions and percentage of total for each aircraft and combined figures are provided. Take-off times are provided in local time for the East Coast.

	C-141		C-5		C-17		COMBINED	
TIME	#	%	#	%	#	%	#	%
0001-0400	8	11.1	12	15.8	4	18.2	24	14.1
0401-0800	7	9.7	9	11.8	2	9.1	18	10.6
0801-1200	10	13.9	7	9.7	5	22.7	22	12.9
1201-1600	14	19.5	12	15.8	2	9.1	28	16.5
1601-2000	21	29.1	19	25.0	6	27.3	46	27.1
2001-2400	12	16.7	17	22.4	3	13.6	32	18.8
TOTAL	72	100%	76	100%	22	100%	170	100%

Table 4: Take-off time by block.

The figure below gives a graphic representation of the take off times by time block.

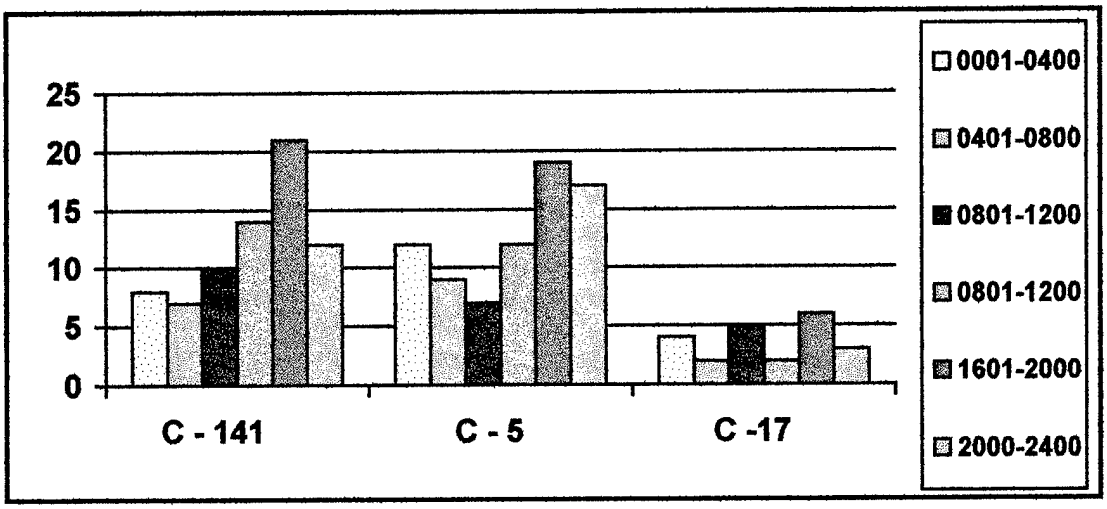

Figure 2: Graphic Representation Of Number Of Missions Departing By Time Group

For all aircraft types the largest number of take-offs occurred in the afternoon, with the 1601-2000 time block having significantly higher numbers in the C-141 and C-5.

LANDING TIMES:

Table 5 presents data on the number of missions which land at their destination during the potential morning circadian nadir of the aircrew. This information is correlated with average duration of these missions (with comparison to the aircraft mean duration). Also presented is the number of these missions which depart for the transatlantic destination during the 1600-2000 time block. This is of significance, because of those missions landing in the predicted circadian nadir, these missions departing in the late afternoon are presumed to be the missions most likely to extend the time awake for the aircrews.

	C - 141		C -5		C -17		TOTAL	
	#	%	#	%	#	%	#	%
MISSIONS LANDING 0200-0600	12	16.7	24	31.6	5	22.8	41	24
TAKE-OFF TIME OF 1600-2000	8	10.8	10	13.2	3	9.1	21	12.4
MEAN DURATION (CHANGE FROM MEAN)	10.85 h (-0.33)		11.15h (+1.15)		12.08 h (+.99)		11.17h (+.53)	

TABLE 5: Missions landing within the circadian nadir of the aircrew.

These figures show that of those missions landing at the circadian nadir, 8 of the 12 C-141, 10 of the 24 C-5 and 3 of the 5 C-17 departed during the 1600-2000 time period. Based on the crews normal sleep-wake cycles, most would be expected to be awake by 0800, and have difficulty sleeping further during the normal morning waking cycle. Pre-mission preparation (3.5+ hours) would prevent an afternoon nap prior to beginning the duty day. These missions which have the highest risk for circadian desynchronosis effects are also on average for the C-5 and C-17 almost an hour longer than the grouped average of all missions.

DELAYS:

Evaluation of delays did not demonstrate any correlation with take-off time or projected landing time. Due to the specific search criteria chosen, the actual increased mission time of each delay could not be calculated. As would be expected, if delays occurred during the

intermediate stop, the length of the stop was frequently extended. Prolonged delays also caused some crews to crew-rest in the delay location.

OTHER OBSERVATIONS:

As mentioned previously, many of the missions evaluated were only part of a multi-day transatlantic trip. Crew-rest data was incomplete for many of the follow-on days, but it was noted in many multi-day trips that there was frequently not time for recovery sleep after 3 days of flying. This type of trip profile can produce accumulated sleep debt and fatigue issues similar to those found by Bisson and Neville in their Desert Shield/Storm studies (3,35).

STUDY LIMITATIONS:

There are several significant limitations to this study. As a descriptive study without specifically correlating the potential crew fatigue with questionnaires or other objective measures of fatigue, it is limited in the conclusions it can reach. As previously stated, assumptions made regarding degree of risk of fatigue will have to be further studied in the population identified as at highest risk. There is no way to determine which missions had augmented crews, and whether inflight napping was used as a fatigue countermeasure on the missions. The use of an estimated pre-flight time of 3.5 hours may tend to underestimate the actual duty day, as some pilots may have to awake before the actual "alert" time to arrive on base in time for preflight duties. Pre-flight time was not added to total mission time due to the problem of estimating this accurately. Landing time does not in reality reflect the end of the duty day, but a time after which fatigue related incidents

pose less risk to the crew and aircraft.. There is the potential for input error into the data base and error in transposition to worksheets, and in calculation of local times and total mission times. The missions that were eliminated due to incomplete information could have varied significantly from the mean, and their exclusion may have affected results. The small number of C-17 missions limited stastical significance of some findings.

CONCLUSIONS AND RECOMMENDATIONS

The transatlantic missions expected to have the highest risk of combining fatigue with circadian desynchronosis are those which depart in the afternoon/evening (1600-2000) from the US location and land at the transatlantic destination after 14-18 hour mission duration. Over 12% of flights fit this criteria. Although there were statistically significant differences between C-141 and C-5 mission duration, there is not a great difference from an operational standpoint. The primary factor for the C-5 having a shorter mean mission duration was the reduced number of missions with intermediate stops. The C-17 mission durations and profiles are similar to those of the C-5 and C-141. It is still to be determined how the smaller crew size on the C-17 will affect crew performance during these "high risk" missions. The crew size on the C-17 more closely resembles that of civilian aircraft, but length of the duty day allowed for military pilots is significantly longer, and multiple day taskings more demanding than those of civilian pilots (53). A further study using objective measures of fatigue should be targeted at these missions to provide better understanding of these effects. Efforts should be made by mission schedulers, whenever operationally feasible, to consider the potential for the combination of fatigue and circadian

desynchronosis in planning a mission. Improved mission scheduling practices may have an additional benifit of reducing aircrew frustration with "the system", enhancing the possibility for pilot retention during a time of increasing pilot separations (2).

The decrement in performance which is associated with fatigue and circadian desynchronosis presents a significant challenge to AMC aircrews. Motivation and increased vigilance during critical phases of flight have helped AMC maintain an admirable safety record. Increasing aircrew awareness of fatigue countermeasures will be an important aspect in reducing the effect of fatigue (4, 14). Proper use and timing of naps is an important countermeasure which should be stressed. The Air Force leadership must ensure that proper facilities for crew-rest, and dining and exercise facilities are available to the aviators. Support personnel should be available so that aircrews avoid spending valuable crew rest time in nonproductive endeavors. The "Scientific Review of AMC Crew Rest Policy and Fatigue Issues" is a valuable document for Air Force leaders. Recommendations made in this report need to be strongly considered. The flight operations, scientific and medical communities must continue working together to improve the quality of life, and safety of our most valuable resource, the men and women aviators.

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