AD P002991

AIRCREW FATIGUE DURING EXTENDED TRANSPORT, TACTICAL, AND COMMAND POST OPERATIONS

William F. Storm
Crew Technology Division
USAF School of Aerospace Medicine
Aerospace Medical Division (AFSC)
Brooks Air Force Base, Texas 78235

SUMMARY

Self-ratings of subjective fatigue and sleep logs provide a simple and useful means of evaluating aircrew fatigue during real-world operations involving large numbers of participants working irregular schedules. Evaluations of extended USAF operations involving transport, tactical, and airborne command post systems are reviewed. Following onboard crew rest on C-141 transport aircraft flying 8- to 9-hour missions, aircrew performance in simulator missions was significantly deteriorated and accompanied by reports of severe fatigue. Tactical aircrews are being trained and evaluated in unit flying at the fast pace expected in the first crucial days of an armed conflict. Flying 2 to 3 sorties a day for a week or more resulted in reports of only moderate fatigue. Daily fatigue was ameliorated by a night of quality sleep. During a 30-hour airborne command post mission, crew fatigue was moderate and not suggestive of compromises in performance. After mission completion, severe levels of fatigue were reported.

INTRODUCTION

The Crew Performance Branch of the USAF School of Aerospace Medicine (USAFSAM) has used a variety of psychobiological measures to evaluate crew fatigue in both airborne and ground operations. The measures have been selected and developed to allow flexibility and to minimize interference with operational duties, daily schedules, and personal activities. The procedures are simple and, after a brief explanation, most can be completed without supervision. A self-administration methodology has proven to be a convenience, if not a necessity, for simultaneously collecting individual data from a large number of crewmen located at different duty stations and working irregular schedules.

The core of our field measurement battery has been self-ratings of subjective fatigue and daily sleep logs. The subjective aspect of fatigue--the feeling of being tired--has considerable face validity. The Subjective Fatigue Checklist (SAM Form 136) was developed at the School in the 1950's (Fig. 1). The scale development methodology used to create the checklist was state-of-the-art at the time and is still highly regarded. It is an undimensional scale of 9 equal-appearing (based on expert judgment) intervals ranging from very refreshed to extremely tired. It employs a forced-choice response format which is also regarded as an excellent technique.

The Subjective Fatigue Checklist is useful in operational studies, not only because it meets the measurement criteria of reliability and validity, but because it is brief, readily understood, easily completed, and simple to score. The checklist requires less than a minute to complete and results in an integer score ranging from 0-20 (arbitary units) with lower scores indicating greater fatigue. Interpretation of the subjective fatigue scores is based on both relative values and absolute scores. In general, scores of 12 or above indicate feelings of alertness and are interpreted to mean fatigue is not affecting crew performance. Scores of 11 down to 8 indicate moderate feelings of fatigue. Scores of 7 and below indicate severe feelings of fatigue. While more research is required to establish a firm relationship, there is some evidence that fatigue scores of 7 to 4 may indicate performance impairment and that scores of 3 or less very likely indicate degraded performance on complex, demanding tasks. This categorization of the fatigue scores is based mostly upon observation and to a lesser extent upon data collected in both operational and laboratory studies.

Circadian (time-of-day) variation is known to occur for subjective fatigue. For the typical day worker, feelings of alertness and freshness prevail during morning and afternoon, while feelings of fatigue become more prevalent in the late afternoon and evening. Feelings of fatigue can be considerable when an individual is required to be awake during normal sleeping hours (2200-0600). The baseline relationship between Subjective Fatigue Checklist scores and oral temperatures collected simultaneously from the same subjects over three consecutive days is presented in Figure 2. Because of this established circadian variation, analyses and interpretation of subjective fatigue scores must often consider the time of day the data were collected.

During most operational tests, we have found it useful to administer the fatigue checklist about once every four hours, although in some situations it has been more practical to tie its administration to the termination of an operational event rather than to a scheduled time. The Sleep Survey (SAM Form 154) is usually completed once a day (Fig. 3). It simply documents the total hours slept during each 24-hour period and requires about a minute for completion. When given the opportunity, subjective fatigue ratings and sleep histories are also collected for a few days immediately before (baseline) and after (recovery) the operational test. The availability of referent baseline data and subsequent recovery data often provides the basis for recommendations pertaining to crew rest requirements generated by the operation under study. The desirability of collecting data from operational crewmen while they are off-duty and at home provides further impetus for a simple, self-administration methodology.

We have used other capabilities and procedures in various field studies. These include other paper-and-pencil surveys, biochemical analyses of urine samples, oral temperature, and heart rate. However, this presentation will concentrate on subjective fatigue responses and sleep histories reported during real-world operations requiring extended duty periods in three different types of USAF airborne operations: transport, tactical, and command post. Many of the requests we receive from operational commands and test agencies are for general human factors support to assist in evaluating the effects of new equipment on the man-machine interface and overall mission performance. While we typically include at least a modest evaluation of fatigue in such tests, there is seldom any involvement of an extended mission factor. The three tests reported here are unique in this respect; in each case the main objective was to evaluate the effect of extended mission duration on crew fatigue.

C-141 INFLIGHT CREW REST

This test evaluated the concept of resting off-duty aircrews while airborne on a C-141 transport aircraft. Military Airlift Command (MAC) aircrews flying long-range intercontinental missions must enter crew rest on the ground after completing a basic 16-hour duty day. While the aircrew enters crew rest--or is staged--the mission aircraft usually continues on manned by a fresh crew. The staged crew is assigned to another mission upon completion of their minimal crew-rest period. Military Airlift Command planners have identified this approach to resting aircrews as a primary limiting factor to having airlift rapidly available for use in overseas theaters. Availability of crews to continue missions beyond staging points is dependent on these crews being properly rested. Current planning factors allow a 9- to 15-hour delay for staging crews to rest at some enroute staging point where the follow-on mission is to be launched. The follow-on mission can be an airland or an airdrop mission and can include a full crew duty day. The Military Airlift Command directed an evaluation of methods to reduce the time between a sudden execute order and the time when the first mission aircraft to arrive overseas can be launched for in-theater missions.

One possible solution was to use palletized crew-rest capsules that could be loaded on C-141 aircraft to provide a facility within which staged crews may rest while airborne and enroute to the staging base. This approach could reduce a staged crew's initial delay from the 9 to 15 hours required for crew rest down to a 3-hour operational stop for refueling and upload of cargo. However, this approach could be limited due to availability, cost, and sleeping capacity of the crew-rest capsules. Therefore, an austere approach, using standard medical litters, was also evaluated for feasibility as an alternate airborne crew rest mode.

For the record, it must be noted that USAFSAM personnel served only as remote consultants for this test. The field trials were planned and implemented by staff personnel assigned to the planning and medical offices at the Headquarters of the Military Airlift Command. They are to be commended for conducting a well-designed field study that incorporated evaluation of operational performance. The blending of real-world missions with high-fidelity simulator missions provided a veridical and safe means of evaluating the impact of aircrew rest procedures on aircrew performance.

The test consisted of four missions; two departed from Charleston Air Force Base (AFB), South Carolina, and two departed from McGuire AFB, New Jersey. Each mission was comprised of a U.S.-Europe leg, a 3-hour layover, and a return Europe-U.S. leg. Flying times for each leg ranged from 8.0-9.5 hours. Crew fatigue and ensuing performance were evaluated in four round-trip crews and four staged crews. Round-trip crews departed the continental United States (CONUS) and flew the test aircraft to Europe. After a 3-hour refueling stop, they returned directly to their home base while resting onboard in either the capsule or the litters. Staged crews from the same home base were prepositioned in Europe in crew-rest status 12-24 hours prior to the scheduled return departures. One such staged crew joined each mission for the return leg to CONUS. On the Europe-CONUS leg of the Charleston missions, the round-trip crews rested in the capsule and the staged crews rested in the litters. On the return leg of the McGuire missions, the round-trip crews rested in the litters and the staged crews rested in the capsule.

Onboard crew rest during the return legs was also evaluated for intervals both in- and out-of-phase with normal home station sleep times. One mission from each U.S. base departed home station in the morning hours (0930 EST, 1430 Z) so that the return leg departed Europe as evening fell on the U.S. East coast (2100EST, 0200 Z). The other mission from each base departed home station in the evening (2130 EST; 0230 Z) so that the return leg departed Europe as the morning hours occurred on the U.S. East coast (0900 EST; 1400 Z). In the first case, the return leg temporally aligned with the normal home station sleep period for the test crews. In the latter case, the return leg aligned with the daylight hours at home station.

Subjective Fatigue Checklist ratings were collected from the round-trip crews approximately one hour after departure from home station and, again, one hour prior to arrival in Europe. On the return leg, fatigue ratings were collected from both the round-trip crew and the staged crew one hour after departure and one hour prior to arrival at home station. Sleep records were maintained by each crewman for 24 hours prior to home base departure and throughout the mission. Upon arrival at home base, both round trip and staged crews flew a 3.5-hour simulator mission which was evaluated by a flight examiner. A final fatigue rating was reported by each crewman immediately after completion of the simulator mission.

Each crew was comprised of 2 pilots, 2 flight engineers, and 1 or 2 loadmasters. Although subjective data were collected from all the crewmen, the data from the loadmasters were not included in the evaluation because their work schedule is typically different from that of their fellow crewmembers on the flight deck, and loadmasters do not participate in simulator missions. Each crewman participated in only one test mission.

The CONUS-Europe legs of each mission were routine channel missions which the participating aircrews had experienced several times previously. Summary schedule, sleep, and fatigue data for CONUS-Europe mission segments are presented chronologically in Table 1. The two crews who flew the morning (0930 EST) departures from home base reported about 6 1/2 hours of sleep for the previous night. Crews flying the evening (2130 EST) home-base departures reported 9+ hours of sleep for the previous night. In about 20 studies, it has been our experience that USAF aircrews typically acquire 7.5-7.75 hours of ad lib nightly sleep. The requirement to report for duty at least 2 1/4 hours prior to scheduled departure resulted in the morning crews reducing their sleep by about one hour while the evening departure crews "slept-in" for an extra hour or so. It can be noted that most of these crewmen, regardless of departure time, retired at about 2330-2400 the previous evening.

An hour after departure from home base both the crews flying the morning and the evening mission reported subjective fatigue ratings indicative of feeling fresh and alert. An hour prior to arrival in Europe the crews reported mild fatigue levels, typical response patterns for transatlantic missions of 8-10 hours duration. Even though on-duty, one or two members of some of the crews acquired short naps during the CONUS-Europe leg. These rest periods are encouraged when the mission workload permits.

TABLE 1

MEAN SCHEDULE, SLEEP, AND FATIGUE DATA
FOR CONUS-EUROPE LEGS

	ROUND TRIP; IN-PHASE	ROUND TRIP; OUT-OF-PHASE
PREDEPART CONUS SLEEP	6.6 HR	9.3 HR
CONUS DEPART TIME	0930 EST	2130 EST
FATIGUE 1-HR POST DEPART	13.0	12.0
ENROUTE SLEEP	1.3 HR	0.6 HR
FATIGUE 1-HR PRE ARRIVAL	9.9	10.4
EUROPE ARRIVAL TIME	1830 EST	0530 EST

Summary schedule, sleep, and fatigue data for the Europe-CONUS return legs are presented in Table 2. The staged crews reported about 8 hours of sleep prior to departing Europe. An hour after departure, all of the round trip crews reported considerable fatigue while the staged crews reported little or no fatigue. Under each scheduling condition the amount of sleep acquired in the capsule and litters was very similar. Therefore, for the purposes of this report, these data were combined. Both the round trip crews and the staged crews reported 5-6 hours of onboard sleep on the return missions which were in-phase with the home base sleep period. Round trip crews and staged crews assigned to rest onboard during return legs which occurred out-of-phase with the home base sleep period reported only 2-3 hours of sleep. One hour prior to landing at home station, all of the crews reported mild to moderate levels of subjective fatigue.

Crews that departed Europe at 2100 EST on the return leg were evaluated in the simulator during the morning hours at home station. Crews that departed Europe at 0900 EST were evaluated in the simulator during the night at home station. None of the crews performed at acceptable levels. Regardless of the time of day tested (and, therefore, whether the return leg occurred in- or out-of-phase with the home station sleep period), the round-trip crews demonstrated about 8 serious deviations per mission while the staged crews demonstrated about 4 serious deviations per mission (Table 2). Most problems were in the areas of crew coordination, judgment, and use of checklists. The examiners noted slurred speech, lengthy discussion of usually routine procedures, and a general slowness at making decisions. Post-simulator subjective fatigue ratings corresponded with the levels of performance. The round-trip crews reported severe fatigue upon completion of the simulator mission. The staged crews also reported strong feelings of fatigue, although their fatigue scores were not as low as those of the round-trip crews. Based on these behavorial and operational findings, it was concluded that aircrews cannot reliably fly a safe follow-on mission after resting onboard an airborne C-141. The longer a crewman is onboard, whether on-duty or in crew-rest, the more fatigued he becomes.

TABLE 2

MEAN SCHEDULE, SLEEP, AND FATIGUE DATA FOR EUROPE-CONUS LEGS

	ROUND TRIP; IN-PHASE	STAGED; IN-PHASE	ROUND TRIP; OUT-OF-PHASE	STAGED; OUT-OF-PHASE
PREDEPART EUROPE SLEEP	N/A	8.2 HR	N/A	8.1 HR
EUROPE DEPART TIME	2100 EST	2100 EST	0900 EST	0900 EST
FATIGUE 1-HR POST DEPART	7.4	11.5	7.4	12.4
ENROUTE SLEEP	5.8 HR	5.4 HR	3.2 HR	2.0 HR
FATIGUE 1-HR PRE ARRIVAL	7.9	11.0	7.0	9.0
CONUS ARRIVAL TIME	0640 EST	0640 EST	1830 EST	1830 EST
SERIOUS SIMULATOR DEVIATIONS	7.0	2.5	9.5	5.0
FATIGUE POST SIMULATOR	4.1	7.4	4.2	7.0

A 7, A-10, AND F-4 SORTIE SURGE

To achieve and maintain total operational readiness, USAF tactical aircrews are being trained and evaluated in unit flying at the fast pace expected in the first crucial days of an armed conflict. Called "sortie surges", a unit may be required to perform a month's flying in a week's time. In response to requests from operational commands, we have evaluated aircrew fatigue during four sortie surge exercises. The objective of these studies has been to assess the impact of flying demanding multiple missions for several consecutive days on acute and cumulative fatigue. Two of the surges were conducted at Myrtle Beach AFB, South Carolina, and involved A-7 and A-10 aircraft. The other two surges both involved F-4 aircraft and occurred in the Republic of Korea and West Germany.

During each of the surges, a Sleep Survey was collected daily from each crewman upon his reporting to the squadron. A Subjective Fatigue Checkcard rating was collected after each sortie. While sorties were flown everyday in all four surges, most crewmen had a few days on which they flew no sorties. Data were not collected from crewmen on days they did not fly.

Statistical analyses were selected to detect systematic changes in fatigue scores both across-days and within-days of each surge exercise. Several factors complicated the analyses. The number of sorties per day and the time of day the sorties occurred varied as a result of scheduling requirements and cancelled missions. Therefore, for the purposes of within-day analyses, the daily sorties were parceled into four time intervals based on sortie termination or landing times; (A) an early morning interval, (B) a midday interval, (C) an afternoon interval, and (D) an evening interval. Not all possible sortie/time-interval combinations occurred and there was a wide range in the frequency of those that did occur. Each analysis tested for aircrew effects, day effects, time-interval effects, and sortie-within-time effects.

The evaluation of an A-7 squadron flying a two-week sortie surge provides representative findings for all four of the surge exercises. The exercise was conducted with less than 24 hours notice and was initiated with a simulated deployment flown over the Southeastern United States. The deployment started at 0700, was of about 8 hours duration, and began and ended at Myrtle Beach AFB, the A-7 pilots' home base. During the next 7 days of the exercise the surge requirement was 64 sorties a day; during the last 7 days the goal was 36 sorties a day. The two-week surge period was extended one additional day as a result of a serious mechanical problem common to all the aircraft. The seventh day was a "down" day for the necessary repairs. Because of this intervening shutdown and the accompanying unscheduled crew rest, data were not collected on the seventh day, and data collected on the following day (day eight) were excluded from some of the analyses. All the sorties were flown between 0600 and 2100 hours.

Thirty-one pilots each flew 8-15 sorties during the first eight days of the surge, with each pilot flying 0-3 sorties per day. Twenty-eight of these pilots each flew 6-11 sorties during the last seven days, with each pilot flying 0-2 sorties per day. Separate statistical analyses were performed on days 1-6 and days 8-15. No statistically significant ($p<.05$) between-day differences were found for mean hours slept per night or for mean daily fatigue score. The pilots averaged 8.1 (range: 7.6 - 8.6) hours of nightly sleep during the surge. The average daily postmission fatigue score was 11.8 (range: 11.5 - 12.2) for days 1-6 and 12.0 (range: 11.4 - 12.5) for the last 8 days.

Within each day of the surge, feelings of fatigue increased in relation to the number of sorties flown, with complete recovery occurring by the start of each successive day. This pattern is apparent in Figure 4 for the first six days of the surge. The day-to-day consistency in the absolute values of the fatigue scores reflects the absence of a cumulative (across days) fatigue effect.

Statistical analyses of within-day changes in fatigue scores were possible after grouping the daily postsortie scores into four time intervals: (A) 0600 - 1000; (B) 1000 - 1400; (C) 1400 - 1800; and (D) 1800 - 2100 hours. During both the first six days and the last eight days of the surge, the mean fatigue ratings reported after completion of the first sorties reflected no fatigue, regardless of the time-of-day the first sortie occurred (Fig. 5). As was very generally presented in Figure 4, the pilots became progressively more fatigued following the second and third sortie (Fig. 5), with statistically significant overall sortie-within-time effects occurring during days 1-6 and days 8-15 ($p<.001$ in both cases).

Specific statistical comparisons considered differences between pairs of sortie for a given time, between adjacent times for given sortie, and between first and last times for a given sortie. Additionally, subtests analyzed "best" available comparisons by collapsing data across time intervals for sortie comparisons or across sorties for time-interval comparisons. The results for days 1-6 and days 8-15 are summarized in Table 3. Significant statistical differences reinforced the general overall trend presented in Figure 4; subjective fatigue increased with each sortie flown, while time-of-day had little or no systematic effect on postmission fatigue scores.

The subjective fatigue and sleep findings for the other three sortie surges were very similar to those for the A-7 surge. Moderate levels of fatigue were reported at the end of each duty day after flying three and, occasionally, four sorties. The daily fatigue was ameliorated by a night's sleep, and cumulative fatigue did not occur over the one- to two-week surge intervals. In each case, the moderate levels of subjective fatigue generated by the surge schedules were complemented by reports of accurate bomb-range performance by the aircrews throughout each surge.

Two factors common to all four of the surges contributed to the abeyance of operationally meaningful levels of fatigue. First, each of these surges was conducted at the aircrews' home bases, permitting them to both perform in familiar operational environments, and to rest and sleep in the comfortable surroundings of their own residences. Second, seldom was a crewman's normal day/night schedule interrupted. Most of the sorties occurred during daylight hours, and rest and sleep occurred during normal nighttime intervals. It has been well established that performance can be maintained on well-learned tasks by highly motivated people for several days, provided a good night's sleep is acquired daily. We have not yet had the opportunity to evaluate aircrew fatigue during tactical sortie surges involving nighttime and/or around-the-clock operations at remote, austere sites.

TABLE 3

STATISTICAL FINDINGS (p VALUES) FOR SPECIFIC PAIRED COMPARISONS OF FATIGURE SCORES REPORTED DURING A-7 SORTIE SURGE

SORTIE COMPARISONS

SORTIES	TIME-INTERVAL *	DAYS 1-6	DAYS 8-15
1 vs 2	B	.463	<.001
1 vs 2	C	.087	.001
1 vs 3	C	<.001	<.001
2 vs 3	C	.039	.009
1 vs 2	D	.002	<.001
2 vs 3	D	.914	-
1 vs 3	D	.008	-
1 vs 2	B+C+D	<.001	<.001
2 vs 3	C+D	.158	-
1 vs 3	C+D	<.001	-

TIME-INTERVAL COMPARISONS

SORTIE	TIME-INTERVALS	DAYS 1-6	DAYS 8-15
1	A vs B	.070	.170
1	B vs C	.446	.095
1	C vs D	.465	.801
1	A vs C	.234	.841
1	A vs D	.860	.924
2	B vs C	.620	.314
2	C vs D	.070	.702
2	B vs D	.005	.114
3	C vs D	.933	-
1+2	B vs C	.833	.068
1+2+3	C vs D	.637	-
1+2	C vs D	-	.882

* Time-interval A:0600-1000; B:1000-1400; C:1400-1800; D:1800-2100.

E-4B 30-HOUR MISSION

The Air Force Test and Evaluation Center (AFTEC) conducted a 45-day initial test and evaluation of the prototype E-4B Advanced Airborne Command Post. A major objective of the test was to evaluate the extended mission capability of the system, as both the Strategic Air Command and National Emergency Airborne Command Post (NEACP) require continuously airborne operational capability in contingency situations. NEACP is the Emergency Airborne element of the Joint Staff and is an alternate command center of the National Military Command System. NEACP provides the National Command authorities with the emergency means essential for accurate and timely decisions, including the communications required for reliable transmission of those decisions with a minimum of delay, for the direction of U.S. military forces. To assess the extended duration capability of the system, a 30-hour continuously airborne test mission was flown. At the request of the AFTEC Command Surgeon, we evaluated crew fatigue associated with the extended mission.

The 30-hour mission departed Andrews AFB, Maryland at 0730 CST (0830 EST), 6 February, and landed at Offutt AFB, Nebraska at 1330 CST, 7 February. Prior to the extended mission, all test participants were briefed on the purpose, procedures, and data-collection schedule so that each crewman could assume major responsibility for the proper and timely collection of his own data. The 66:1 ratio of crewmen to study director and the need for at-home data collection during postmission off-duty days is a case-in-point for the use of a self-administration methodology.

Collection of subjective fatigue ratings and sleep logs began at about 0800 CST shortly after takeoff on the morning of 6 February. From that time on, fatigue ratings were collected at 4-hour intervals around-the-clock during the mission, and at 4-hour intervals during typical waking hours for the 3 1/2 days after the mission. A Sleep Survey was completed at 0800 (or upon awakening) each day. This data collection schedule served only as a general guideline. Test participants were never awakened for data collection. Some fatigue ratings were collected as much as 60-90 minutes before or after scheduled times to allow for uninterrupted work and sleep periods. The USAFSAM study director was onboard during the mission to observe and collect completed material. Immediately after landing at Offutt AFB, each participant was given a supply of Subjective Fatigue Checkcards and Sleep Surveys to take home for self-administration during the 3 1/2 day postmission period. The study director was available daily at the Offutt AFB E-4B test office to collect completed forms at the convenience of the test participants.

The SAM subjective fatigue and sleep data from the 66 test participants were grouped into six functional crew categories: 9 flight crewmen (5 pilots, 2 navigators, 2 flight engineers), 4 stewards, 17 radio and teletype operators (COMM), 12 radio maintenance personnel (AMS), 10 aircraft maintenance personnel (OMS/FMS), and 14 members of the NEACP battle staff. Although the 4 stewards formed a very small sample, their unique duties and schedule necessitated treating them as an independent group. Such a small sample, however, severely limits statistical description and analyses, so these data were not subjected to all evaluations.

Data were incomplete for various reasons. As expected, some of the 66 crewmen slept through one or two data-collection intervals. During the mission, no data were collected from the OMS/FMS and NEACP groups at 0400 because they were all sleeping. After the mission, some participants departed Offutt AFB on other missions before postmission data collection was completed. A few participants never submitted any postmission data. Mean values presented in text, tables, and figures are composites of estimates from the various analyses.

The amount of sleep acquired was documented for the day before the mission, the 30-hour mission, and each of the 3 days following the mission. An initial analysis of all 5 days indicated that mission sleep data had significantly greater variability than the data for the other 4 days. Therefore, four separate analyses were performed, in which each nonflying day was individually compared with the mission-day (Table 4). Because of missing data, best-estimates of means were calculated for the various comparisons, resulting in two sets of means for the mission day: one set for comparison to premission sleep (upper portion of Table 4), and one set for comparison with mean hours slept during each postmission day (lower portion of Table 4). As noted earlier, postmission data were not available from the NEACP crewmen. Significant group x day interactions occurred in each of the four paired analyses involving the mission day.

Premission sleep was moderately to severely reduced from normal for all groups but stewards. Standby-alert duty schedules required some COMM, OMS/FMS, and NEACP personnel to remain awake during the 20 hours preceding takeoff at 0730 on 6 February. During the mission, the overall average sleeping time was 7 hours. The NEACP staff received the least sleep (4.7 hours), and the OMS/FMS group the most (10.1 hours). However, the overall range for individual sleep data during the mission was very large: 0.9-20.0 hours. The responsibilities and duties of the various groups determined when they could acquire some sleep. For instance, most of the OMS/FMS personnel were much busier during the hours preceding takeoff than when airborne, while the opposite was the case for the stewards. The sleep acquired during the mission by most (72%) of the participants was fragmented into two or three intervals separated by an hour or more. A fifth analysis simultaneously compared the sleep data for the 4 nonflying days. Only the day effect was significant ($p < .001$). The least sleep was acquired premission (5.3 hours), and the most was acquired the first postmission night (10.1 hours). Typical amounts of sleep occurred on the second and third postmission nights (8.1 and 7.8 hours, respectively).

TABLE 4

MEAN HOURS SLEPT DURING PREMISSION, MISSION, AND THREE POSTMISSION DAYS

Premission vs Mission Day

	Flightcrew	Stewards	COMM	AMS	OMS/FMS	NEACP
Premission	6.1	7.0	4.9	5.8	5.5	4.3
Mission	6.3	5.4	7.5	7.8	10.1	4.7

Mission vs Each Postmission Day

	Flightcrew	Stewards	COMM	AMS	OMS/FMS
Mission	6.1	5.3	8.0	7.9	10.5
Postmission-1	10.5	10.5	11.2	9.0	9.1
Postmission-2	8.6	8.5	8.6	7.4	7.8
Postmission-3	8.2	10.3	8.1	7.0	7.6

Severe levels of subjective fatigue were not reported during the 30-hour mission, but moderate levels did occur as the mission progressed into the evening and early morning hours (Figs. 6 and 7). Through 1200 on 7 February, a typical circadian pattern occurred for both the overall crew means (Fig. 6) and, allowing for minor variations, the means for each crew-group (Fig. 7). Even after a night of reduced and disrupted sleep, feelings of fatigue subsided during the last 6 hours of the mission which, in this case, corresponded with the time of day (0800-1400) when most people feel alert and fresh. In both Figures 6 and 7, this time-related improving subjective state is depicted by the general pattern of increasing scores (less subjective fatigue) from 2400 to 1200 on 7 February.

Both mission and postmission mean subjective fatigue scores are presented in Figure 6 for 0800 and 2000 on each day of the study. The format of Figure 8 highlights some group differences in patterns of change during the mission. Comparing the fatigue levels for each group at 0800/6 February and 0800/7 February, essentially no difference occurred for the flightcrew and AMS personnel; the COMM group reported a moderate increase in fatigue, while the OMS/FMS group felt less fatigued. The OMS/FMS group acquired a large average amount of sleep (>10 hours) during the mission. Most of that sleep (96%) occurred during the first 24 hours of the mission. The recuperative value of this sleep, even though acquired in the airborne-mission environment, was reflected in the reduced fatigue reported by the OMS/FMS personnel at 24 hours into the mission.

For each crew category, the greatest amount of subjective fatigue (lowest scores) reported at any time during the study occurred at 2000 on the evening of 7 February after landing at Offutt AFB (Figs. 6 and 8). The mean score of only 4.2 for the flight crew at 2000, while based on only 5 of the 9 members (the others had already retired for the night), was particularly indicative of intense feelings of fatigue. The effects of the previous 40-48 hours, combined with the opportunity to "let down" upon entering home-base postmission crew rest, contributed to the high levels of subjective fatigue reported by most participants on this first evening after mission completion.

After a night of extended good quality sleep at home (10.1 hours), the crews were considerably recovered and refreshed on the first postmission day, as indicated in Figures 6 and 8 by the elevated fatigue scores on 8 February. Comparing scores reported at 0800 and 1200 (NEACP omitted) during the last portion of the mission (7 Feb) with those reported at the same times after the first night of recovery (8 Feb), a significant increase ($p=.002$) in daily mean fatigue score occurred; the average score was 10.9 during the final airborne hours and 13.4 a day later.

The mean subjective fatigue scores reported during the first and second complete postmission days (8 and 9 Feb), plus the need for only normal amounts of sleep on the second postmission night, indicated complete recovery on the morning of 9 February, about 40 hours--and more importantly, two nights of restful sleep--after mission completion. The relatively lower subjective fatigue scores reported on 10 February, the last day of postmission evaluation, are probably not related to mission effects. While no definite explanation can be offered, 10 February was a Saturday, and the conclusion of the 45-day test period was celebrated the Friday night before by several of the test participants. The postmission fatigue scores collected at 0800, 1200, 1600, and 2000 on 8, 9, and 10 February were submitted to analysis of variance for all participating crew-groups but the stewards, for whom too much data were missing. Significant crew-groups ($p=.019$), day ($p=.026$), and time-of-day ($p=.004$) effects occurred (Table 5). The time-of-day effect reflected typical circadian variation. Additional testing of the day means indicated no change from 8 to 9 February, but a significant decrease in score from 9 to 10 February.

TABLE 5

MEAN POSTMISSION SUBJECTIVE FATIGUE SCORES FOR E-4B CREW-GROUPS, TIMES-OF-DAY, AND POSTMISSION DAYS

CREW GROUP	MEAN FATIGUE SCORE
FLIGHTCREW	14.0
COMM	14.0
OMS/FMS	10.7
AMS	11.4
TIME-OF-DAY	
0800	13.2
1200	13.4
1600	12.5
2000	10.6
POSTMISSION DAY	
8 FEB	13.5
9 FEB	13.5
10 FEB	11.6

In summary, the subjective fatigue levels reported during the 30-hour E-4B mission were moderate and not of a magnitude associated with compromises in performance and safety. Although not of the best quality, the sleep acquired inflight in the bunks, in the duty and passenger seats, and even on the floor was of restorative value and contributed to the general absence of severe fatigue during the mission. The high quality of the meals and the comfortable bioenvironment also contributed to the maintenance of crew motivation and morale. Notable levels of subjective fatigue were reported on the afternoon and evening following mission completion and entry into post mission crew rest. After the first postmission night, in which an average of 10 hours of sleep was acquired (2-3 hours more than usual), the crewmen were considerably recovered and felt generally refreshed throughout the first complete postmission day. After the second postmission night of an uninterrupted, typical amount of sleep, the crewmen had recovered sufficiently to resume normal ground and flight duties. The subjective fatigue scores were of normal amplitude and pattern.

Generalisations are limited for the crew fatigue findings for this single 30-hour mission. The scheduling involved only one normal sleep period during the airborne mission. Greater crew fatigue could result from a 30-hour mission starting in the early evening hours because two normal sleep periods would be disrupted, the second during the final hours of the mission. The severe subjective fatigue reported after the 30-hour mission, about 36 hours after takeoff, is cause for some concern when considering the NEACP requirement for a 72-hour continuously airborne capability. Although this finding was partially a consequence of entering postmission crew rest, the data suggest that severe levels of fatigue could occur during the last half of a 72-hour continuously airborne mission. The current fatigue findings for the 30-hour mission cannot be extrapolated to a 72-hour mission, as any accumulation of fatigue would be nonlinear.

NAME AND GRADE | TIME/DATE

INSTRUCTIONS. Make one and only one (√) for each of the ten items. Think carefully about how you feel RIGHT NOW.

STATEMENT	BETTER THAN	SAME AS	WORSE THAN
1. VERY LIVELY			
2. EXTREMELY TIRED			
3. QUITE FRESH			
4. SLIGHTLY POOPED			
5. EXTREMELY PEPPY			
6. SOMEWHAT FRESH			
7. PETERED OUT			
8. VERY REFRESHED			
9. FAIRLY WELL POOPED			
10. READY TO DROP			

SAM FORM SEP 76 136 SUBJECTIVE FATIGUE CHECKCARD

Figure 1. Subjective Fatigue Checkcard.

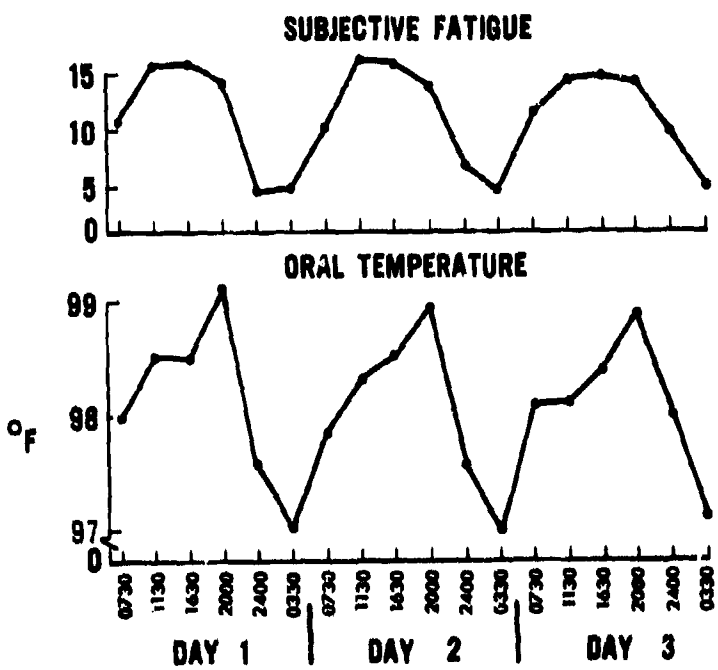
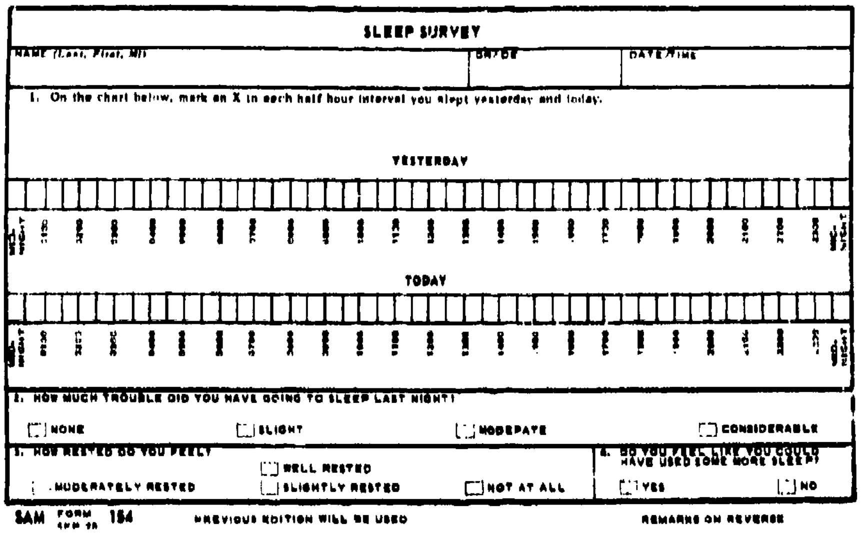


Figure 2. Typical circadian patterns for oral temperature and self ratings of subjective fatigue.



SLEEP SURVEY

NAME (Last, First, MI) | GR/DE | DATE/TIME

1. On the chart below, mark an X in each half hour interval you slept yesterday and today.

YESTERDAY

TODAY

2. HOW MUCH TROUBLE DID YOU HAVE GOING TO SLEEP LAST NIGHT?

[ ] NONE [ ] SLIGHT [ ] MODERATE [ ] CONSIDERABLE

3. HOW RESTED DO YOU FEEL?

[ ] WELL RESTED

[ ] MODERATELY RESTED [ ] SLIGHTLY RESTED [ ] NOT AT ALL

4. DO YOU FEEL LIKE YOU COULD HAVE USED SOME MORE SLEEP?

[ ] YES [ ] NO

SAM FORM 154 PREVIOUS EDITION WILL BE USED REMARKS ON REVERSE

Figure 3. Sleep Survey.

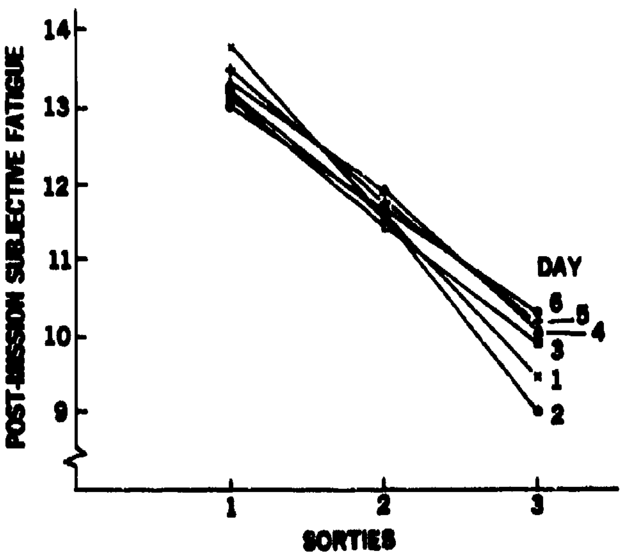


Figure 4. Mean subjective fatigue scores reported by pilots during days 1-6 of the two-week A-7 surge.

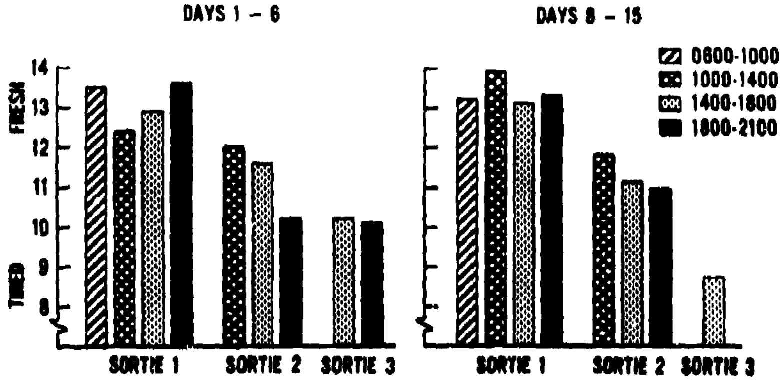


Figure 5. Mean subjective fatigue scores reported for A-7 sorties terminating during early morning, midday, afternoon, and evening time-intervals.

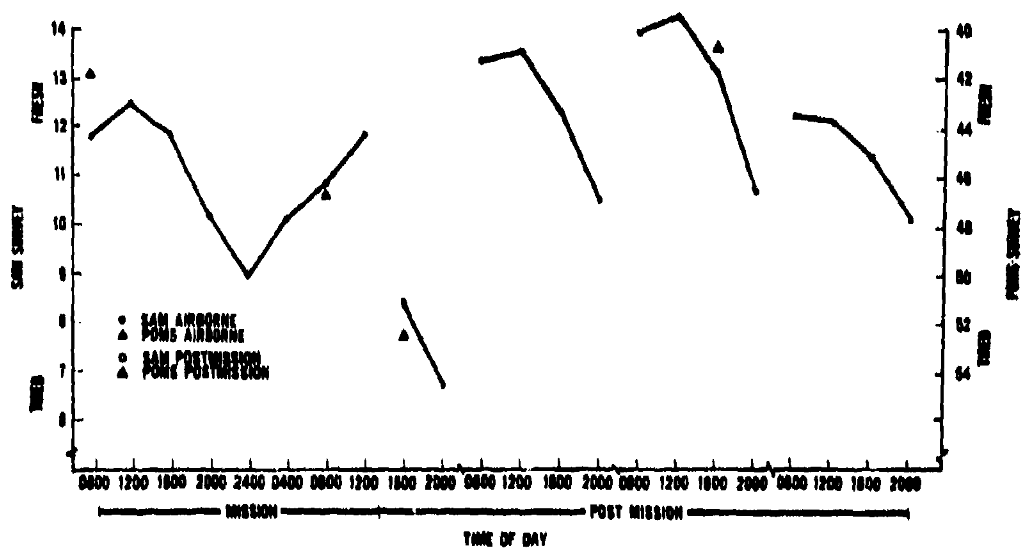


Figure 6. Mean subjective fatigue scores reported during the E-4B 30-hour mission (6-7 February) and the 3 1/2 day postmission interval (7-10 February).

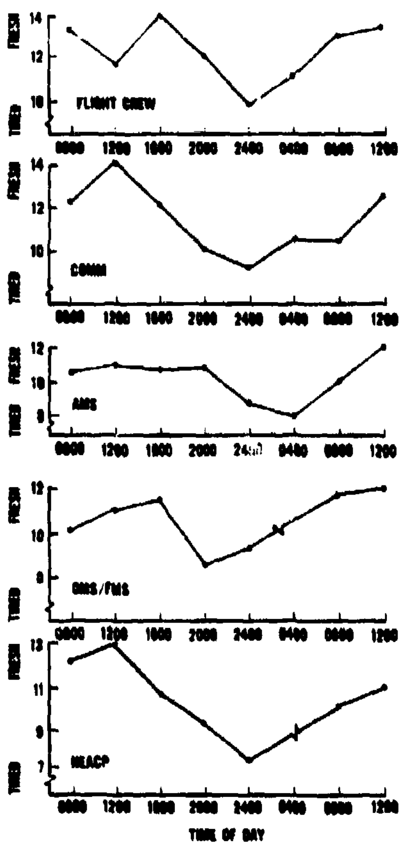


Figure 7. Mean subjective fatigue scores reported by five functional crew-groups during the E-4B 30-hour mission.

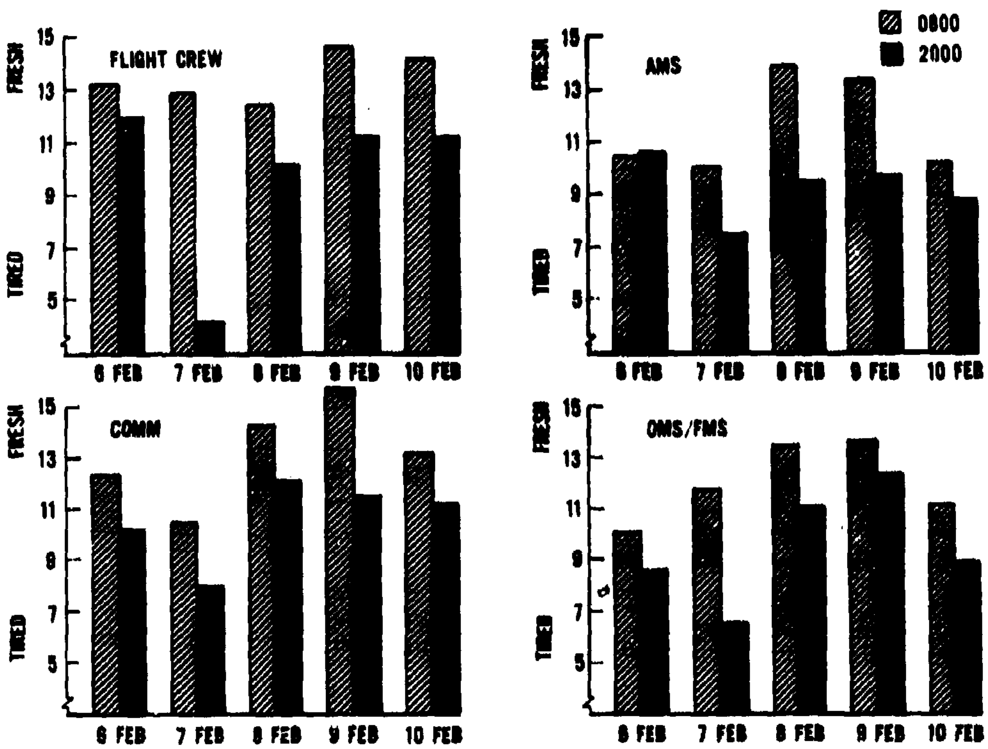


Figure 8. Mean subjective fatigue scores reported by four crew-groups during (6-7 February) and after (7-10 February) the E-4B 30-hour mission.

DISCUSSION

DR A F SANDERS (NL)

To what extent do you think studies carried out only using ratings of subjective fatigue have anything to say about the real state of affairs? How does one know that the subject's rating reflects his performance?

AUTHOR'S REPLY

I too am concerned that we have to rely on subjective ratings. If I could measure performance more directly I would do so, but we do not yet have the techniques which will allow us to determine performance in many of the operational situations which we are requested to investigate. Thus many of the operations which we have investigated have been organised by others and we have to do the best we can under the circumstances to evaluate crew fatigue. You will note that I spoke of aircrew fatigue and not aircrew performance. Whenever it is possible we attempt to relate subjective fatigue ratings to performance as, for example, in the first study with the C-141. There we used the assessments of performance made by the flight examiners. I believe that assessment of fatigue and workload in the field can be improved by incorporating performance measures such as SWAT (see paper No 20). Frequently we have to base our recommendations on operational matters, on less information than one would wish. However, even with a limited amount of information, we can make recommendations which will improve air operations.

PROF H URSIN (NO)

I would like to support the use of subjective ratings. It is preferable, of course, to use objective measures but subjective fatigue scales do correlate with other indicators, not only performance but also the incidence of slow waves in the EEG. As I will detail in my paper (No 22), I believe that subjective reporting can be of considerable value.

DR C E BILLINGS (US)

Indeed subjective rating scales are one of the measures which most consistently correlate with performance over a wide range of situations.

DR J R ALLAN (UK)

I would also like to defend subjective measures. It is sometimes claimed that objective measurements, for example tracking performance, are somehow more valid. Thus the demonstration that one stress produces a greater tracking error than another may well have no significance whatsoever in terms of effectiveness of a mission. Objective measures require as much validation in terms of relevance to operational effectiveness as do subjective measures.

DR A RIECK (GE)

Should not the minumum value of the rating in the scale of fatigue during the 30 hour flight occur at 04.00 hr rather than 24.00 hr?

AUTHOR'S REPLY

I believe that this question relates to the study of the E4B mission where we found that the average subjective fatigue scores were lower at midnight than at 04.00 hr in the morning. This result did not raise any concern. There was probably more activity at 04.00 hr than at midnight and this almost certainly disturbed the rhythm which occurs in undisturbed individuals. The scores at midnight and 04.00 hr were low. Furthermore, one frequently finds fluctuations so that the lowest score may occur at midnight or at 04.00 hr or even sometimes at 06.00 hr; there is a lot of individual variation.

E E HOWARD (UK)

Would it not be valuable for unit flight medical officers to administer fatigue check lists to aircrew on a routine basis so that they could monitor the type of flying performed and the intensity of fatigue?

AUTHOR'S REPLY

Operational Flight Surgeons do ask us increasingly for advice and support to investigate fatigue during local exercises. I hesitate to give aircrew the additional paperwork which routine monitoring of fatigue by check lists would involve. I believe, however, that such paper and pencil tasks can, with value, be used by the local Flight Surgeon to monitor fatigue in specific operational exercises. In providing advice to Flight Surgeons on fatigue in aircrew I have found the review by Drs Klein and Wegmann (AGARDograph No 247, Significance of Circadian Rhythms in Aerospace Operations by K E Klein and H M Wegmann) on circadian rhythms and the AGARD publication by Dr Laverne Johnson (AGARDograph No 193, The Operational Consequences of Sleep Deprivation and Sleep Deficit by L C Johnson and P Naitoh) of considerable value as reference documents for the Flight Surgeon in the field.

DR C E BILLINGS (US)

A further AGARD publication written recently by Gp Capt Nicholson on fatigue (AGARDograph No 270, Sleep and Wakefulness Handbook for Flight Medical Officers by A N Nicholson and B M Stone) will also be of great value to Flight Surgeons in the field - for whom it was primarily written. It is well written and provides a very good exposition of the current state of knowledge in this area.

DR L C BOER (NL)

I would like to comment that Dr Storm's and Kimball's papers (No 21 and 20 respectively) may create the impression that certain measures, such as fatigue scales or thermal stress, can predict performance. It should be realised that measuring performance is, of course, always superior when the aim is to predict impairment or failure of performance.

DR C E BILLINGS (US)

The chair notes that both Dr Storm and Dr Kimball were very careful not to suggest that their measures were in any sense predictive of performance.