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# AEROMEDICAL ASPECTS OF CH-47C HELICOPTER SELF-DEPLOYMENT (OPERATION NORTHERN LEAP)

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20. ABSTRACT

In August 1979, the US Army accomplished its first transatlantic helicopter flight. Four CH-47C helicopters departed Fort Carson, Colorado, and landed in Heidelburg, Germany, with intermediate stops in Iowa, Pennsylvania, Maine, Canada, Greenland, Iceland and England. A flight surgeon accompanied the mission to provide medical support and assess aircrew workload, stress and fatigue. Direct observation, interviews and questionnaires were used to gather data.

Respiratory infections were experienced by approximately 50% of the mission crew during the 14 day journey. These were attributed to wide climate variations and inadequate crew rest during the first half of the mission. Daily pre-flight questionnaires showed highest levels of stress occurred at the start of the mission and decreased to a constant level once the mission was underway. Daily post-flight data demonstrated that cockpit workload increased appreciably with deterioration of weather during the latter part of the mission. Time at the flight controls and mission conditions during flight were found to be the greatest contributors to pilot fatigue; whereas, crew chiefs reported frequent time zone changes and poor facilities at stopover points to be their greatest causes of fatigue.

The results demonstrated the feasibility of self-deployment and the need for medical support of such missions.

## ACKNOWLEDGMENTS

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## TABLE OF CONTENTS

## LIST OF ILLUSTRATIONS

## LIST OF TABLES

# INTRODUCTION

Concern over the past few years has been raised about the need for additional medium lift helicopter capability in Europe, and the inability, using current means, to provide these resources to the theater of operations in sufficient time to adequately support a major conflict. This has led to increased interest on the part of the Vice Chief of Staff of the Army and the Training and Doctrine Command (TRADOC) in the concept of self-deployment of CH-47 helicopters from the Continental United States (CONUS) over the North Atlantic to Europe. The importance of self-deployment to the Army was emphasized at the Army Aviation Review Program in December 1978 and reported by Thompson in the Aviation Digest (1979). A feasibility study was conducted by the Directorate of Combat Developments (DCD), US Army Transportation School (USATSCH), Fort Eustis, Virginia, and published in final draft in March 1979 (Brown 1979). Following this study, TRADOC tasked USATSCH to conduct a concept evaluation deployment utilizing four CH-47C helicopters and augmented crews from the 179th Aviation Company, Fort Carson, Colorado. The deployment was scheduled to leave Fort Carson on 1 August 1979 and arrive in Germany on 9 August 1979 with overnight stops in Iowa, Pennsylvania, Maine, Canada, Greenland, Iceland, Scotland and England.

The US Army Aeromedical Research Laboratory (USAARL), Fort Rucker, Alabama, was invited to participate in the exercise in May 1979. Research personnel were requested to address the data requirements cited in the USATSCH Test Design Plan (paragraphs 3.2-3.4): "To provide information on safety and human factors related to self-deployment of CH-47C/D aircraft" (Heehn and Moore 1979). More specifically, the information sought was the following:

1. Guidance in the procurement of certain items of life support equipment for the mission.

2. Evaluation of aircrew stress, fatigue and medical problems during the conduct of the mission.

3. Medical training and support for the mission.

The first item was accomplished through discussions between the Aviation Safety Officer for the mission and various USAARL personnel. Special polarized sunglasses were supplied by the USAARL Human Tolerance and Survivability Division for use on the mission.

Items two and three were accomplished by the participation of a USAARL flight surgeon during all phases of mission training and as an in-flight observer on one of the four helicopters during conduct of the mission. A military research psychologist from the USAARL Field Research and Biomedical Applications Division also assisted in crew preparation prior to departure from Fort Carson and accompanied the mission as a data collector on the Air Force C-130 support aircraft.

The mission departed Fort Carson on 6 August 1979 after numerous delays due to maintenance, manpower and equipment installation problems. The four helicopters arrived in Germany on 20 August 1979 after experiencing further delays en route due to maintenance problems, weather, and European flying prohibitions arising from local noise abatement laws.

Successful completion of the mission constituted the first US Army transatlantic helicopter crossing. Two Air Force HH-3E helicopters accomplished a nonstop transatlantic helicopter flight in 1967 utilizing aerial refueling. Aeromedical data and discussions of this mission were reported in July 1969 in Aerospace Medicine (Brown and others; Buckley and Hartman; Hale and others).

## MATERIALS AND METHODS

### AIRCRAFT

Four CH-47C aircraft were equipped with internal auxiliary fuel tanks capable of holding 2000 gallons of JP-4 fuel (Figures 1-3). Two of the aircraft were outfitted with Omega navigation systems and two with primary inertial navigation systems. Each of the four aircraft was also equipped with a cruise guide indicator, a high frequency communications radio, a glideslope receiver, and a radar altimeter in addition to the standard avionics and instrumentation in the CH-47C aircraft. Personnel rescue hoists were installed in three of the four aircraft. Each aircraft was also provided with additional soundproofing material in its interior.

### LIFE SUPPORT EQUIPMENT

Each aircraft was supplied with a covered ten-man life raft and several cases of standard Army in-flight food rations. Each aircrewman was supplied with a fully equipped Army aviator's survival vest integrated with a US Navy LPA-2 life preserver. A quick-donning, total immersion, cold water survival suit was also supplied for each airman. During overwater crossings, each aircrewman wore a Canadian cold water survival jacket under the survival vest and LPA-2. A detailed description and listing of life support equipment may be found in the USATSCH project report (Heehn and Moore 1980).

FIGURE 1. The CH-47C Helicopter in Flight Over the North Atlantic.

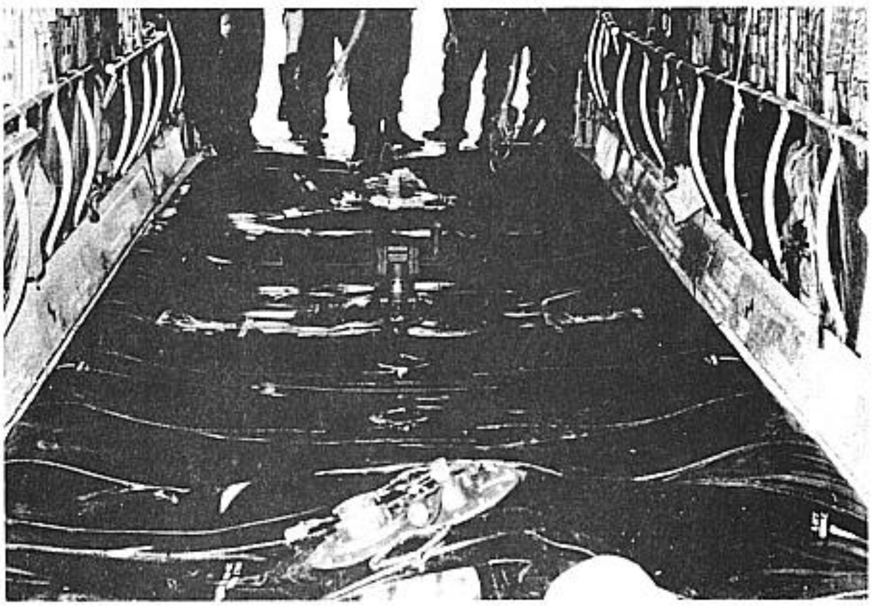

FIGURE 2. The Internal Auxiliary Fuel Tank Empty.

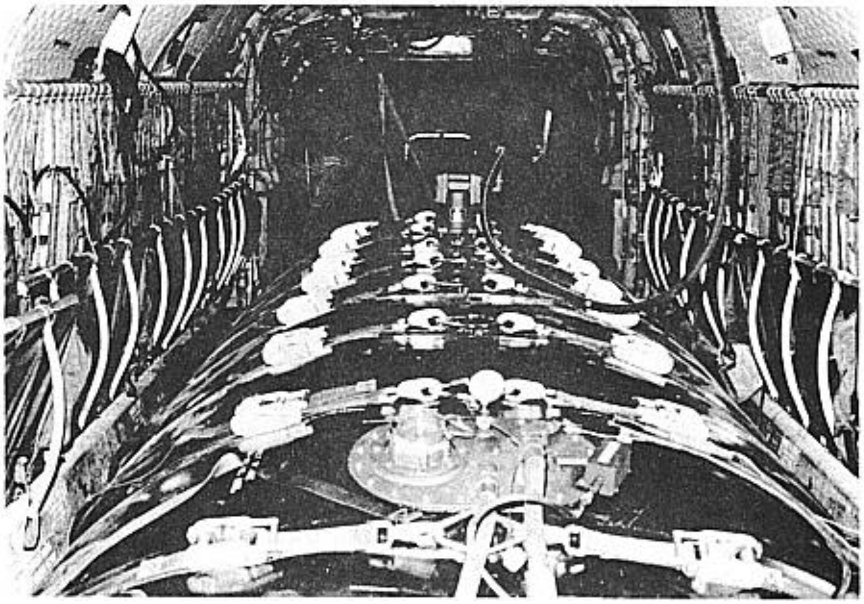

FIGURE 3. The Internal Auxiliary Fuel Tank Approximately Half Full.

MEDICAL EQUIPMENT

The flight surgeon carried an emergency medical drug and equipment kit. (See Appendix A for a listing of the contents of this kit.) Each aircraft had one first aid kit augmented to include aspirin and acetaminophen tablets, Desenex ointment, multivitamins, chewable antacid tablets and Chapstick lip balm. To monitor internal aircraft temperature and humidity, the flight surgeon also carried a psychrometer.

EVALUATION MATERIALS

Numerous questionnaires were utilized for the purpose of conducting crew evaluations on aircraft systems and collecting data on aircrew stress and fatigue. The medical questionnaires were: (1) a daily pre-flight, (2) a daily post-flight, and (3) a post-mission. (See Appendix B.) The pre-flight questionnaires concentrated on self-imposed stresses and their patterns of change during the mission. Self-imposed stresses included cigarette, alcohol and caffeine consumption, and hours of sleep per 24-hour period. These were correlated with four mood scales designed to assess tiredness, anger, fear, and overall disposition prior to the start of each flight day. The post-flight questionnaires attempted to measure the pilots' perceptions of weather, their level of fatigue at the end of each flight, and allowed the pilots to weigh the effects of eight potential flight stresses (including an "other" category) as contributors to their overall level of fatigue. The post-mission questionnaire contained several narrative type questions along with another group of stress factor scales designed to compare mission stresses with fatigue for the entire mission. Other questionnaires used during the mission are described in the USATSCH project report (Heehn and Moore 1980). The flight surgeon maintained a daily medical log to record his observations and keep track of individual medical problems and medications dispensed.

## PERSONNEL

Each aircraft carried five aircrewmembers. Three were pilots assigned to the aircraft, one was a senior crew chief who was designated the "flight engineer," and one was a junior enlisted specialist. A sixth person on each aircraft was one of the four evaluators. These were the test and evaluation officer for USATSCH, the flight surgeon, the project manager, and a Canadian Forces representative. The latter two evaluators were currently rated CH-47 pilots. The four evaluators rotated across all of the four aircraft during the nine flight days of the mission. Two of the three pilots assigned to each aircraft were from the 179th Aviation Company, Fort Carson, and the third was from a Reserve or National Guard component. The project manager and the Canadian Forces representative also functioned as fourth pilots on their respective aircraft and contributed to the aeromedical data collection.

## TRAINING

Specialized training for the mission began in May 1979 when the primary and alternate crews and evaluators all attended the Naval Overwater Survival Training Course at Pensacola Naval Air Station. All attendees completed the swimming and sea survival phases. A few aircrewmen including the Aviation Safety Officer (ASO) received additional training in cold water survival at the Canadian Water Survival Course. This included an actual experience with hypothermia and its effects.

Pilots received training in navigation using the Omega and inertial navigation systems, high latitude navigation, and CH-47 water operations. Pilots and crew chiefs trained in the operation of the personnel hoist in water rescue operations. Emergency procedures were reviewed in the CH-47 simulator training conducted at Fort Rucker in early June 1979. Weather training and training in the use of high frequency radios were conducted en route. First aid training was cancelled due to numerous scheduling conflicts. One class on the medical effects of alcohol was conducted by the flight surgeon prior to start of the mission.

Much of the flight training syllabus was curtailed after three unfortunate aircraft mishaps prior to the start of the mission. An accident at Fort Carson involved four mission personnel doing an autorotation at high gross weight in which the crew chief reported he heard a loud "bang" in the rear of the aircraft and the pilot experienced a sudden loss of rotor RPM resulting in the aircraft falling uncontrollably about 20 feet to the ground. There were no injuries but the aircraft was destroyed. The cause of this accident is still undetermined. The second mishap resulted from failure of the aircraft's combining transmission. This accident was followed by the grounding of all CH-47's with Series 2 combining transmissions and required subsequent replacement with the newer Series 8 combining transmissions. The third mishap occurred during a Boeing demonstration of running landings to the water at Trinidad Reservoir, Colorado. The aircraft struck the water at high velocity causing incident damage to four rotor blades and the engine cowling with flame-out of one engine. These accidents served to further heighten anxiety prior to the start of the mission.

AEROMEDICAL EVALUATIONS

Prior to the start of the mission all medical records, flight physicals, and immunization records on mission personnel were reviewed by the mission flight surgeon. Routine flight physicals, immunizations, and special medical consultations were accomplished. Particular note was made of problems which might be aggravated by the length of the mission, lack of adequate medical facilities en route or long exposure to noise and vibration. Pre-mission audiograms were done on all personnel; however, post-mission audiograms were unobtainable due to lack of adequate facilities in the receiving unit's aviation medicine dispensary in Germany. One enlisted specialist had to be eliminated from the mission prior to its start because of long-standing traumatic arthritis in one knee. It was the professional opinion of the flight surgeon that this condition would have been severely aggravated by continued exposure to vibration during the course of the mission.

Psychometric performance tests and subjective measures of fatigue and short term anxiety were administered at selected stopover points during the mission. These are described in attachments to USAARL's letter to the US Army Transportation School (5 Nov 1979).

Pre-flight questionnaires were distributed at the morning debriefing prior to the start of each flight day and post-flight questionnaires were distributed and completed along with the psychological tests and questionnaires during a debriefing session on the flight line at the conclusion of each flight leg through flight day 8. Non-flying days were used to conduct interviews with individual crewmen by the test and evaluation officer, the psychologist, and the flight surgeon. At the conclusion of the mission, the flight surgeon and psychologist spent 1 duty day conducting individual interviews and testing. At this time the post-mission questionnaire was completed by all crewmen. The flight surgeon also made in-flight measurements of internal aircraft temperature and humidity using a sling psychrometer, and recorded observations on crew rotations, workload and mission conditions.

## CONDUCT OF THE MISSION

The four CH-47C's took off from Fort Carson on 6 August 1979 at 1420 Greenwich Mean Time (GMT). Weather was excellent and the aircraft landed in Davenport, Iowa, at 1940 GMT. Significant problems on this leg of the mission were a fuel leak on aircraft No. 548 and severe vibration on aircraft No. 829. The vibration on No. 829 was caused by failure to properly track a new rotor blade installed the previous day. Weather was excellent en route but temperature and humidity on the ground in Iowa were extremely high (temperature at the airfield was in excess of 100°F (37.8°C)). Time zone change resulted in a loss of 1 hour.

The second leg of the flight departed Iowa at 1420 GMT, 7 August 1979, landing at New Cumberland Army Depot, Pennsylvania, at 1845 GMT. Weather again was excellent. Temperatures in New Cumberland were in the low 90's (33°C). Time zone change resulted in loss of another hour, and the following day, 8 August, was used for maintenance and scheduled inspections of two of the four aircraft.

On 9 August the mission departed New Cumberland at 1330 GMT and arrived in Loring Air Force Base, Maine, at 1855 GMT. Weather remained good with moderate temperatures in the 60's (15°C). Departure was delayed from Loring awaiting a special fitting for one aircraft. The flight continued at 1840 GMT on 10 August and arrived in Goose Bay, Canada, at 2130 GMT. Another hour was lost due to time zone change.

The first overwater leg (Flight Day 5) began with takeoff from Goose Bay at 1230 GMT on 12 August. The flight had again been delayed due to maintenance problems on 11 August. Weather was good en route but a considerable portion of the flight was conducted in

"VFR on top" conditions. Upon arrival at Greenland, it was necessary to let down through the cloud breaks, VFR, and fly up the fiord to land at Narssarssuaq at 1830 GMT. The C-130 support aircraft could not shoot the approach and diverted to Sondestrom.

Departure from Narssarssuaq (Flight Day 6) on 13 August was uneventful, but climbing over the ice cap at high gross weight resulted in two of the aircraft being unable to maintain airspeed over 80 knots. After clearing the icecap a layer of stratus was observed from the sea up to 15,000 feet. After attempting to divert around this to the south, the mission returned to Narssarssuaq where it remained until 15 August due to a combination of weather and maintenance problems.

Takeoff on 15 August was delayed due to a faulty oil pressure selector switch in one aircraft during engine run-up. This was replaced and takeoff was at 1515 GMT with arrival in Keflavik, Iceland, at 2117 GMT. This was a time zone change of 3 hours loss from Greenland. Temperatures were in the low 40's (4.5°C) with a brisk wind. Further mechanical difficulties resulted in the flight remaining in Keflavik until 17 August.

The final water leg of the mission was begun at 0830 GMT on 17 August from Keflavik. Weather was good en route but had deteriorated below visual flight rule (VFR) minimums at Lossiemouth, Scotland, the intended destination. The flight diverted to Prestwick, Scotland, refueled and continued VFR in marginal weather with poor visibility to Mildenhall Royal Air Force Base, England, landing at 1845 GMT.

Due to helicopter noise restrictions in Germany, the flight remained in England over the weekend and took off on Monday, 20 August, for Germany at 1010 GMT. Due to low ceilings at destination, the last leg of the flight was flown under instrument flight rules. The mission arrived in Germany at 1415 GMT, and after removal of the auxiliary fuel tank from one aircraft, it flew a simulated combat mission of about 1 hour to demonstrate combat readiness of both aircraft and crew. Final aeromedical evaluations were completed in Mannheim, Germany, on 21 August 1979.

## RESULTS AND DISCUSSION

### HUMAN FACTORS ASSESSMENT

Observations of workload among the four crews demonstrated that each member of the five-man crews was busy throughout most of each flight leg. Additional navigational tasks, high frequency radio operation, fuel management, and required 30-minute recordings of engine and aircraft systems instruments kept the flight deck crew fully occupied. The only time one of the three pilots was able to rest for more than a few minutes was when the evaluator on each aircraft relieved him on the flight deck.

Although the flight engineers and crew chiefs were less busy than the pilots, they too were occupied most of the time. Their duties included 30-minute "ramp checks" of hydraulic systems and transmissions, and fuel transfers. Each fuel transfer took approximately 30 minutes to transfer fuel from the internal auxiliary tank to the main fuel tanks. Transfers were done approximately every 1! hours. It became obvious during the first few flight legs that during transfers the internal auxiliary tanks needed to be "cinched down" by manually tightening the numerous straps attaching the fuel tank to the aircraft floor. This was done to prevent sloshing of fuel with resultant oscillations in the aircraft center of gravity and also to prevent accumulation of air in the tanks. This task occupied both crew chiefs in each aircraft a considerable amount of time.

During the early hours of each flight, movement between the front and rear of the aircraft was extremely difficult due to the space occupied by the fuel bag (see Figure 3). To get from front to rear or vice versa, one had to crawl almost the length of the aircraft along the top of the fuel bag in a small space between the bag and the ceiling. This was done at the risk of being thrown off either side of the bag into a bulkhead or into the ceiling with any sudden changes in aircraft attitude. After the first fuel transfer in each flight, the bag tended to flatten out and walking over it became much easier.

During the flight two hammocks were attached from side to side across the middle of the aircraft and these were used by the crews when time permitted. Vibration was effectively dampened by the hammocks. One aviator who had been medicated for bronchitis found it was possible to sleep in the hammock fully clothed, including flight helmet and gloves, for almost the entire length of a flight leg. Noise levels were reduced by the additional soundproofing material and the aircrewmen did not wear ear plugs under their SPH-4 helmets.

Each aviator took about 20-30 minutes to eat one meal during each flight leg. Army standard in-flight food packets were compared with Air Force box lunches purchased at Loring, Goose Bay, and Keflavik. In terms of basic nutrition, the two were about equal, but the vast majority of aviators preferred the box lunches as being tastier. Besides being fresher, they contained more variety and did not require heating to improve palatability.

Elimination of wastes was accomplished via a relief tube and a chemical toilet for solid wastes in the rear of each aircraft. Except for the previously mentioned problem of getting to the rear of the aircraft in the early hours of flight, the only other problem experienced with the relief tube was that, on one aircraft, it was too short, necessitating assuming a very awkward position to relieve oneself. The chemical toilets were universally shunned by all aircrewmen, including one aviator in the early stages of gastroenteritis.

Rotation schedules of pilot duties varied widely during the first few flight days, but afterwards a relatively constant pattern emerged among all four crews. Each pilot would fly 1½ to 2 hours at the flight controls, after which he would usually leave the flight deck for a few minutes and the pilot in the troop commander's (TC) seat would take his place. The pilot in the other seat would take over the controls while the fresh pilot in the first seat would assume navigation and communication duties. The pilot in the TC seat would conduct the systems checks and monitor the fuel transfers. The maximum time any pilot stayed "up front" without a break was about 4 hours.

Most aviators complained about wearing the cold water exposure jacket, survival vest and LPA-2 together; a few refused to wear the combination after the first overwater leg. They complained of discomfort along the spine, most prominent at the lower neck, and of feeling too "confined" by the combination. Interference with their handling of the flight controls was rated as moderate by the aviators on their post-flight questionnaires.

Flight surgeon measurements of internal aircraft temperatures varied between a low of 51°F (10.6°C) on the leg from Keflavik to England to a high of 81°F (27°C) on the leg from Davenport to New Cumberland. Wet bulb temperatures varied similarly from a low of 44°F (6.7°C) on the first attempt to leave Greenland to a high of 57°F (13.9°C) on the leg from New Cumberland to Loring AFB. These measurements were made when the aircraft reached their cruising altitude following takeoff, usually about 15 minutes into the flight. Follow-up measurements showed only slight changes from the initial readings; these were most prominent on flight legs with large changes in latitude. These temperatures indicated that the aircraft's internal environment remained comfortable during most of the mission. Two notable exceptions were two aircraft in which the windows blew out in flight. On these aircraft the crews reported they became quite cold. Since the flight surgeon was not on either of these aircraft when these incidents occurred, no actual temperature measurements were taken.

MEDICAL PROBLEMS

Approximately half the primary crewmen became ill at some time during the mission. Most of these problems were upper respiratory infections and were not reported until the end of the mission. However, two of the four aircraft commanders and the aviation safety officer for the mission developed significant medical complications to what at first appeared to be simple upper respiratory infections. One aircraft commander (AC) developed a serious bronchitis which was diagnosed by the flight surgeon during the layover at Loring AFB. He was treated with erythromycin, pseudoephedrine and a cough preparation, and was restricted from performing pilot duties on the leg from Loring AFB to Goose Bay. This was the previously mentioned aviator who spent an entire flight leg in the hammock.

A second AC complained of pleuritic chest pain in Germany at the conclusion of the mission and was found to have bronchitis and a friction rub on auscultation of the right lung. A diagnosis of pleurisy was made and he was treated with erythromycin and high doses of aspirin for two days with significant improvement. The aviation safety officer developed an influenza-like syndrome with both respiratory symptoms and gastroenteritis which became acute during the final flight leg from England to Germany. His illness resolved spontaneously and required no medication.

One other aviator developed a pruritic dermatitis on his buttocks of unknown etiology, for which he received diphenhydramine capsules and hydrocortisone creme. One of the alternate pilots who was flying on the C-130 aircraft developed a severe toothache from an improperly fitted filling and required acetaminophen-codeine tablets for relief. His filling was repaired at Loring AFB. No significant injuries occurred during the mission.

Two factors were seen as major contributors to the amount and type of illnesses seen on this mission. First was the extreme changes in temperature, humidity, and time zones experienced in the first 11 days of the mission. Second was failure of the crews in the early part of the mission to follow adequate crew rest guidelines. This was especially true upon arrival in New Cumberland where many of the aviators, suspecting the aircraft would be down for repairs the next day, socialized until very late getting only 3-4 hours sleep that night. The following morning, numerous minor medical complaints were voiced, and about 30 aspirin tablets were dispensed. This indiscretion was generally abandoned once the mission began the overwater legs.

Medications dispensed included significant numbers of aspirin tablets, pseudoephedrine tablets, and throat lozenges. Erythromycin was the only antibiotic dispensed in significant quantities and most emergency medical supplies were not used. The flight surgeon obtained one refill of his stock of pseudoephedrine tablets in Goose Bay after his first stock was destroyed during a flight leg when his medical kit was strapped in the rear of the aircraft. Vibration appeared to be the cause of the tablets being pulverized, and when moved to the forward section of the helicopter, the problem was resolved. The augmented first aid kits were useful, but the aviators depended appropriately upon the flight surgeon for any medications they needed other than those in the first aid kits.

Post-mission questionnaire data indicated that all personnel felt some level of trained medical support is necessary for this type of mission above the level of regular aircrewmembers with additional medical training. Five believed this could be accomplished at the enlisted medical support level with one or more "flight medics" (a 91B MOS with additional training in flight medicine). Fourteen stated that for a deployment of any size a physician's assistant trained in flight medicine would be necessary; and three, including two of the AC's, felt a flight surgeon was mandatory for deployment of this kind. Statements on the questionnaires showed that lack of en route medical support at some locations, such as Goose Bay and Narssarssuaq, and difficulties in coordinating with local medical authorities such as in Keflavik, prompted this response. The aircrews were also emphatic about the need for first aid training especially cardiopulmonary resuscitation, major trauma and hypothermia.

## AIRCREW STRESS AND FATIGUE

As discussed previously, several different types of assessments were used to obtain data on aircrew stress and fatigue. None of these was entirely satisfactory. Early in this mission, an attitude was fostered among the crews (both internally and externally) that getting the four aircraft to Europe was the only really important aspect of the mission. Because of this attitude and because the questionnaires themselves tended to be somewhat stress producing in men who really were busy with other things, the responses on these questionnaires and tests must be interpreted with caution.

The daily pre-flight questionnaires were designed to gain information on consumption of substances known to be stressful to some extent to aircrewmen and to assess the individual aviator's various moods prior to each day's flight as previously described. In the analysis of data from these questionnaires, data on tea and soft drink consumption were not significant because too few aviators drank tea and soft drink consumption was too dependent on our overnight location. Data from flight days 5 and 8 were not included in the analysis because insufficient pre-flight questionnaires were returned on flight days 5 and 8 for this data to be meaningful.

The data from the pre-flight questionnaires were analyzed using techniques of regression analysis (Draper and Smith 1966, Seber 1977) and canonical correlation (Harris 1975) after plots of the data were studied. The Systems Engineering Laboratory Hybrid Computer 8500 at USAARL was used with programs for general plotting, stepwise regression and canonical correlation (Dixon 1973, Borden and Nuss 1969).

The regression analyses were used to determine which of the eight pre-flight questionnaire variables showed significant variation with time (flight days) and which varied significantly between pilots and crew chiefs. The eight pre-flight variables studied were cigarette, alcohol and coffee consumption, hours of sleep, and the four mood scales (tiredness, anger, fear and disposition). Of the twenty-two aircrewmen studied, nine were identified as non-smokers of which six were pilots and three were crew chiefs. In total there were fourteen pilots and eight crew chiefs studied. In this analysis both flight engineers and crew chiefs were referred to as "crew chiefs."

Cigarette and alcohol consumption were found to be relatively independent of time, but varied significantly between pilots and crew chiefs ($p < .05$) with pilots smoking more but using less alcohol than the crew chiefs. The 8 pilots who smoked averaged between 1½ and 2 packs of cigarettes per man per day. The 14 pilots averaged approximately 2 to 2½ alcoholic drinks during their off-duty hours while the 8 crew chiefs averaged 2½ to 3 drinks.

Coffee consumption, hours of sleep, tiredness scores and anger scores showed significant variations with time. Coffee consumption decreased linearly with time as the mission progressed ($p < .01$) and also showed highly significant differences between smokers and non-smokers ($p < .01$), and pilots and crew chiefs ($p < .05$). At the start of the mission, the pilots who also smoked averaged drinking in excess of 4½ cups of coffee per day. This decreased to an average of just over 2 cups of coffee by flight day 7. Non-smokers and crew chiefs drank less.

Hours of sleep showed a negative inverse ($-1/t$) relationship to time (flight days) starting at a mean of approximately 5½ hours and increasing to approximately 9 hours by flight day 7. Tiredness scores, as expected, varied inversely with time ($p < .05$) showing a lack of adequate rest at the beginning of the mission, which improved as the mission continued, and the crews increased their hours of sleep prior to each flight day.

Anger scores showed the strongest correlation with time varying as $1/t^2$ ($p < .01$). This probably reflected a general settling of people's emotions once the mission left Fort Carson. The rush of last minute preparations, the delays, and the difficulties in local administration and logistics had resulted in the entire team being frustrated and anxious. After the mission left New Cumberland with all four aircraft in a trustworthy state of repair, much of this anxiety and hostility was seen to subside.

Fear and disposition scores were found to be relatively independent of time but showed significant differences between pilots and crew chiefs ($p < .05$) with pilots manifesting more fear and preoccupation than did the crew chiefs. This probably represents the more direct responsibility of the pilots for mission safety during the in-flight phases of the mission.

A correlation matrix was constructed and the data were subjected to a canonical correlation to look for linear relationships among the eight variables independent of time, and to construct two new variables, one representing a linear combination of the four stressors, and the other a linear combination of the four mood scales. For the purposes of this analysis, a Poisson distribution was assumed for cigarette consumption and these counts were transformed using the following formula: $y_i = x_i + .375$ . This would allow for the large number of non-smokers and stabilize the variability among the smokers.

For a p value of less than .05, the following relationships were seen to be significant (see Table 1): Cigarette, alcohol and coffee consumption were all directly related, namely, those individuals who tended to use any one of those three heavily tended to use all three heavily. The same was true for the four mood scales. Those who reported high scores on any one scale tended to report high scores on all four scales.

The strongest correlation (+ .778) was between anger and fear, except, as previously noted, anger was highly time dependent and fear was not. It is interesting to note that hours of sleep appeared independent of all the other variables except the tiredness score (as expected) and fear. It showed a negative linear correlation to both of these such that decreasing hours of sleep resulted in increasing tiredness and fear scores.

The two new variables, $\varepsilon$ representing the linear combination of the stressors, and $\mu$ representing the linear combination of the mood scores, were shown to be directly related with a canonical correlation coefficient of 0.428. The equations are as follows:

$$\varepsilon = 0.24(N_T)-0.24(A)+0.001(C)+0.28(H)$$

$$\mu = -0.06(r)+0.04(a)-0.09(f)+0.04(d)$$

TABLE 1

STANDARDIZED CORRELATION COEFFICIENT MATRIX

| | [CIGS] | ALCH | COFF | SLEEP | TIRED | ANGER | FEAR | DISP |
|---|---|---|---|---|---|---|---|---|
| [CIGS] | 1.0000 | | | | | | | |
| ALCH | 0.2975 | 1.0000 | | | | | | |
| COFF | 0.4346 | 0.2848 | 1.0000 | | | | | |
| SLEEP | -0.1882 | -0.0851 | -0.1612 | 1.0000 | | | | |
| TIRED | -0.0024 | 0.0997 | 0.1199 | -0.3692 | 1.0000 | | | |
| ANGER | -0.1104 | -0.0488 | 0.1286 | -0.1840 | 0.4970 | 1.0000 | | |
| FEAR | -0.1336 | 0.0330 | -0.0133 | -0.2108 | 0.4286 | 0.7782 | 1.0000 | |
| DISP | 0.0566 | -0.0744 | 0.0335 | -0.1791 | 0.2672 | 0.5456 | 0.7217 | 1.0000 |

Values above 0.19 are significant ($p < .05$).

[CIGS] refers to the transformed cigarette counts.

$N_T$ = cigarette consumption (transformed)
A = alcohol consumption
C = coffee consumption
H = hours of sleep

r = tiredness score
a = anger score
f = fear score
d = disposition score

This canonical correlation (equations 1 and 2) was significant (chi-square = 30.7, df = 16, $p < .015$). It showed that cigarette, coffee and hours of sleep had a stimulant effect on the aviators while alcohol had a depressant effect. Increasing this stimulant effect tended to decrease tiredness and fear scores while increasing anger and disposition scores. The disposition score can probably best be thought of as a measure of overall alertness or sensitivity to mission problems.

The post-flight questionnaires were subjected to a simple regression analysis to identify which variables showed a significant relationship with time (flight days). The ten variables studied were physical workload, mental workload, post-flight fatigue, time at flight controls (as a fatigue factor), mission conditions, noise and vibration, mission anxiety, aircraft environment, personal factors, and boredom. A cumulative weather score for each flight day was calculated and the results are shown in Figure 4. It is interesting to note that pilot perception of weather on day 5 was excellent in spite of the fact that the C-130 support aircraft was forced to divert due to the broken cloud ceiling over Narssarssuaq. Four of the ten variables were shown to be time dependent. These were physical workload, post-flight fatigue, mission conditions and mission anxiety (see Figures 5-8). Two of these, post-flight fatigue and mission conditions, tended to parallel the weather scores while mission anxiety was highest during the intermediate overwater flight legs. These subjective findings support adverse weather as a principal cause of increased cockpit workload and fatigue in long flights where terrain avoidance is not a factor. However, changes in circadian rhythms and other factors also probably contributed to the trends seen.

Fatigue data in the post-mission questionnaires for the pilots showed that time at the flight controls and mission conditions were the greatest contributors to fatigue. Overnight facilities, noise and vibration, mission anxiety, and circadian rhythms were less important but still significant causes of fatigue (Figure 9). The crew chiefs felt that changes in circadian rhythms, inadequate overnight facilities, and noise and vibration were their greatest causes of fatigue (Figure 10).

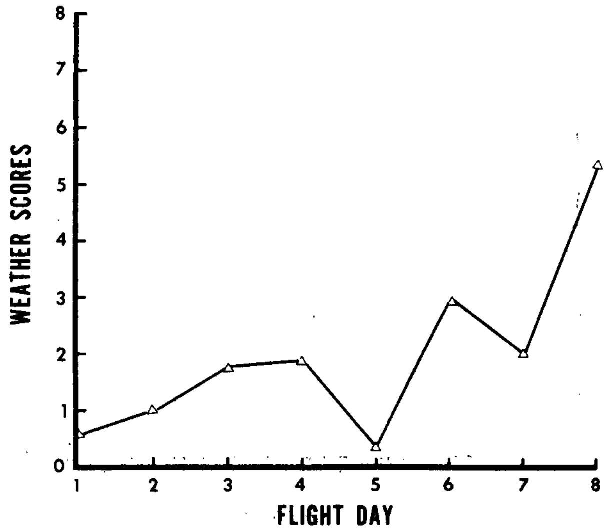


FIGURE 4. Mean Cumulative Weather Scores Versus Flight Day (Post-Flight Questionnaires).

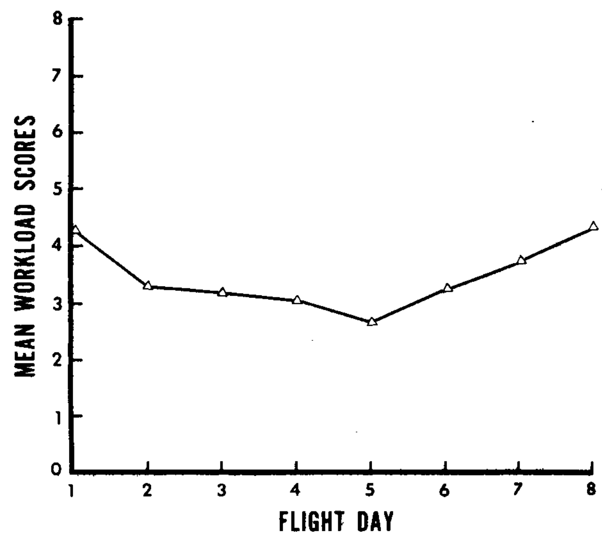


FIGURE 5. Physical Workload Versus Flight Day (Post-Flight Questionnaires).

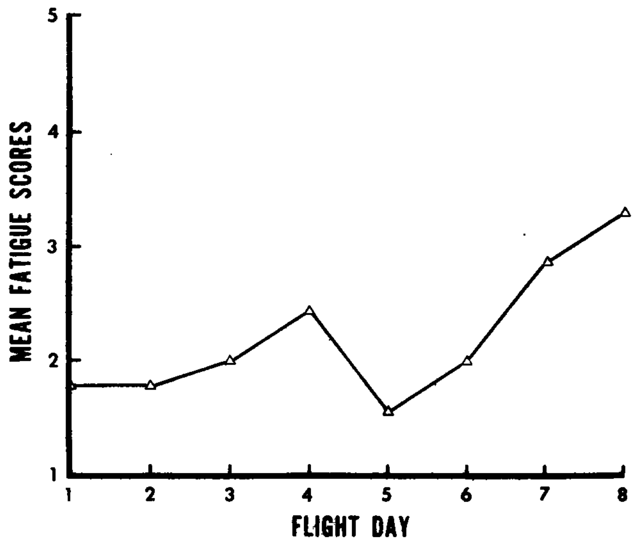


FIGURE 6. Post-Flight Fatigue Versus Flight Day (Post-Flight Questionnaires).

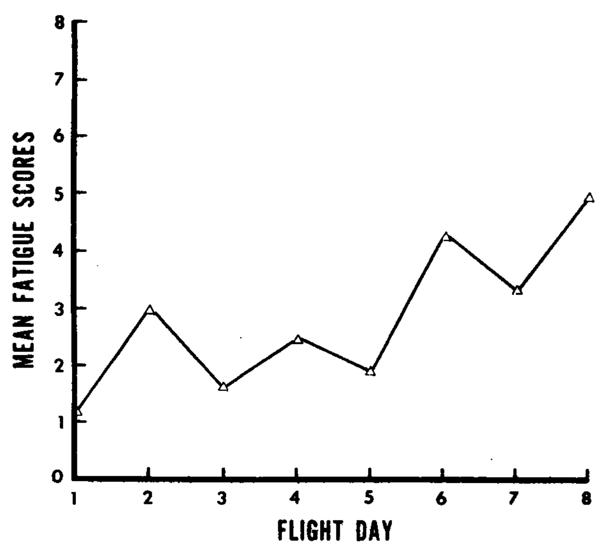


FIGURE 7. Mission Conditions Versus Flight Day (Post-Flight Questionnaires).

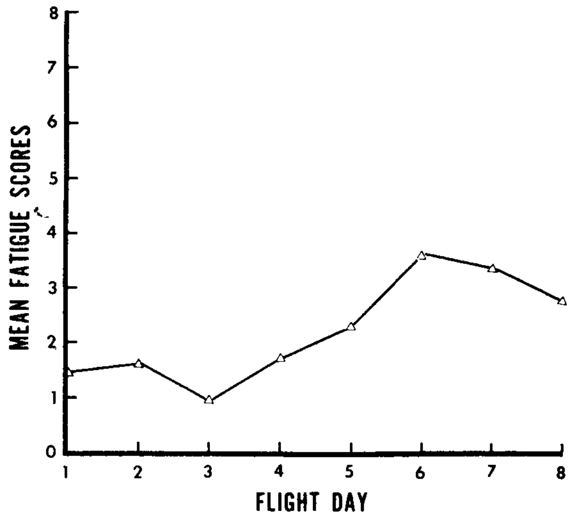


FIGURE 8. Mission Anxiety Versus Flight Day (Post-Flight Questionnaires).

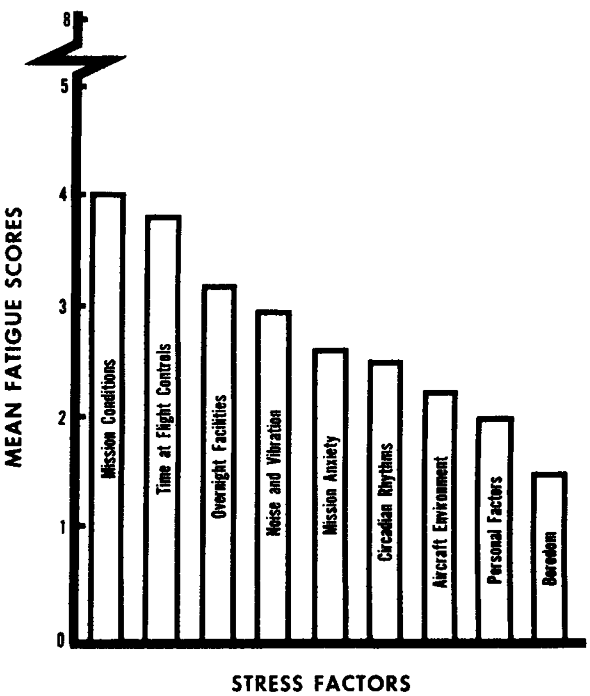


FIGURE 9. Mean Fatigue Scores Versus Stress Factors, as Reported by Pilots on the Post-Mission Questionnaire.

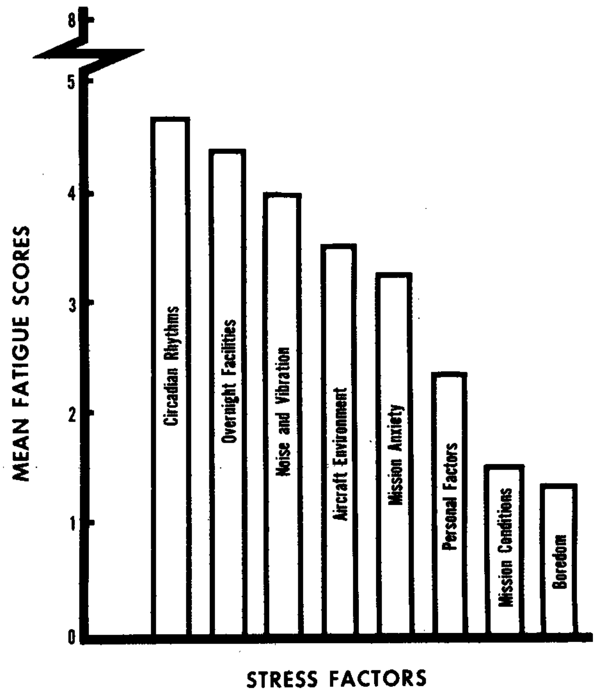


FIGURE 10. Mean Fatigue Scores Versus Stress Factors as Reported by Crew Chiefs on the Post-Mission Questionnaire.

The need for adequate facilities at stopover points especially in terms of maintenance support, parts, and tools was emphasized by both crew chiefs and pilots. Much unnecessary anxiety could have been averted if this support had been better.

To combat the effects of circadian rhythm changes, early takeoff times need to be emphasized every flight day with programmed rest days following any leg which crosses two or more time zones. Crew chiefs felt the effects of the time zone changes more acutely than the pilots as a result of their longer workday. Aircraft environment was seen to be more of a significant factor when the aircraft was overly warm than when it was cool. This may explain the successive decreases in importance of this fatigue factor during the first 3 days of flight with a relatively constant level over the remainder of the mission (the cold part).

Both groups rated boredom as the least significant cause of fatigue. Crew chiefs also rated mission conditions very low as a factor probably because weather had little effect on the performance of their duties. Another cause of fatigue mentioned by many of the aviators was soreness in the buttocks and lower back due to prolonged sitting in the hard aircraft seats. Sheepskin seat covers helped some but not much.

As to what the aircrewmen felt capable of doing upon arrival in Europe, the majority (13) felt they could either fly immediately or in 4-5 hours. The remainder felt the need for rest from 8 hours up to 3-4 days before they felt they would be ready to fly again.

In answer to the question about utilization, 21 out of 22 felt they would prefer to return to CONUS to deploy additional aircraft as opposed to deployment in the theater of operations for normal aviation duties. In discussing their responses to the utilization question, it was seen that most of the aviators favored a self-deployment team concept. These would be specially trained teams of pilots, crew chiefs, medical and maintenance personnel who would ferry aircraft across the Atlantic on a continuing basis.

## CONCLUSIONS AND RECOMMENDATIONS

Operation Northern Leap demonstrated the feasibility of CH-47C self-deployment within certain recognized limitations with regard to aircraft maintenance. Consequently, as an aeromedical evaluation of stress and fatigue, extremes of fatigue were never reached, as the men on this mission consistently out-performed their machines. The major stress associated with this mission appeared to have taken place prior to the start of the mission in the confused "hurry up and wait" atmosphere which surrounded the final days of preparation. This stress was what the aviators perceived and to which they responded with anxiety, and, in some cases, distinct mood changes.

Based on the observations of cockpit and crew workload, a five man crew is probably the minimum essential crew for conducting a self-deployment mission of this type in the CH-47C aircraft. Six would be more comfortable and allow for more rest in flight. Traffic between the front and the rear of the aircraft needs to be minimized when using an internal fuel bladder such as the one used on this mission, and this may necessitate installation of a relief tube in the front of the aircraft.

Rotation schedules are probably best left up to the individual crew within the following recommendations:

1. No pilot should fly at the controls longer than 2 hours and then should have at least a 1-hour break before flying again.

2. No pilot should stay on the flight deck longer than 4 hours without at least a 20-minute break during the flight period.

Because of the severe cold experienced on the two aircraft in which the windows blew out in flight, some temporary window covering should probably be carried on each aircraft to immediately cover a blown out window and preserve a reasonably comfortable aircraft environment.

The survival vest and cold water exposure jacket need to be modified. The jacket is only going to give an aviator a couple of hours survival outside a raft in frigid waters. Therefore, only short term survival equipment, primarily signaling devices are needed in the jacket and vest. Long term survival equipment is already in the raft. The jacket itself is buoyant; therefore, the LPA-2 is probably unnecessary. Eliminating the LPA-2 and the long term survival equipment from the vest would greatly decrease the bulk and weight of the jacket and vest resulting in improved comfort. The vest itself needs to be retained primarily for the "D" ring which is used in hoist rescues.

The need for adequate and responsive medical support was clearly demonstrated to include training, supplies, and professional manpower. First aid training is essential for aircrews participating in this type of mission. It is the professional opinion of the flight surgeon that mission personnel need additional education on the effects of self-imposed stressors such as smoking, excessive use of alcohol and caffeine, and inadequate rest patterns. Additional command attention to crew rest policies and monitoring of alcohol consumption during missions of this type will reduce the potential for disregard of these policies by aircrewmen as a response to the stress of the mission. This would, hopefully, help reduce the amount of cumulative fatigue experienced on a mission of this type.

Finally, the uniqueness of this type of flying for Army aviators suggests the formation of self-deployment teams in the future for most efficient accomplishment of these missions.

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# APPENDIX A

## Contents of

## Emergency Medical Treatment Kit

Contents of

Emergency Medical Treatment Kit

| | |
|---|---|
| Acetaminophen tablets | # 100 |
| Acetaminophen-codeine tablets | # 30 |
| Activated charcoal | 15 grams |
| Ampicillin capsules (250 mgm) | # 100 |
| Atropine (0.4 mgm/cc) | 20 cc |
| Calcium chloride 10% (prefilled syringes) | # 2 |
| Chloramphenicol ophthalmic ointment | # 3 |
| Chloramphenicol ophthalmic solution | 45 cc |
| Cortisporin otic solution | 30 cc |
| D5/Lactated ringers (1000 cc bags) | # 4 |
| Diphenhydramine capsules (50 mgm) | # 30 |
| Endotrachael tubes (assorted sizes) | # 3 |
| Epinephrine 1/1000 (2 cc vials) | # 10 |
| Epinephrine intracardiac injections | # 2 |
| Erythromycin tablets (250 mgm) | # 100 |
| Fluor-I-Strips | # 50 |
| Gauze bandages (assorted sizes) | # 50 |
| Homatropine HBR ophthalmic solution | 15 cc |
| Hydrocortisone creme 1% | 30 grams |
| IV indwelling catheters (#18 and #20) | 2 of each |
| IV butterfly needles (#21 and #23) | 2 of each |
| IV tubing | 4 sets |
| Laryngoscope with straight blades and extra batteries | # 1 |
| Lidocaine 1% | 50 cc |
| Lomotil tablets | # 120 |
| Meclazine tablets (25 mgm) | # 100 |
| Morphine sulfate (10 mgm injections) | # 4 |
| Mylanta tablets | # 100 |
| Novahistine expectorant (4 oz) | # 4 |
| Oral airways | # 2 |
| Oto-ophthalmascope | # 1 |
| Penicillin tablets (250 mgm) | # 100 |
| Prednisone tablets (5 mgm) | # 100 |
| Promethazine tablets (25 mgm) | # 30 |
| Proparacaine ophthalmic solution | 15 cc |
| Prophylactics, condom type | # 12 |
| Pseudoephedrine tablets (60 mgm) | # 100 |
| Sphygmomanometer | # 1 |
| Splints (assorted sizes) | # 6 |
| Stethoscope | # 1 |
| Storage box, tool chest type with double lock | # 1 |
| Swabs, alcohol and betadine | 100 of each |
| Syringes and needles (assorted sizes) | # 10 |

# APPENDIX B

## Aeromedical Research Questionnaires

## DAILY PREFLIGHT QUESTIONNAIRE

1. How many cigarettes have you smoked in the last 24 hours?__________

2. How much alcohol have you consumed in the last 24 hours?___________

3. How many hours of sleep have you had in the last 24 hours?_________

4. Place a mark on the following scale to indicate your current level of restfulness.

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|
| Well Rested | | Marginally Rested | | | Tired | | | Exhausted |

5. How much caffeine-containing beverage did you drink in the last 24 hours?

   Coffee ____________ cups

   Tea ____________ cups

   Soft Drink ____________ 12 oz cans or bottles

6. Place a mark on each of the following scales to indicate your current levels of psychological stress.

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|
| Calm | | | | Nervous | | | | Agitated or Angry |

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|
| Confident | | | | Worried | | | | Frightened |

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|
| Happy | | Satisfied | | Preoccupied | | Sad | | Depressed |

## POST-FLIGHT QUESTIONNAIRE

The first four questions are to obtain a numerical score for weather conditions during this flight period. Circle the correct response.

1. Visibility:

   a. Greater than 7 miles.

   b. 5-7 miles.

   c. 3-5 miles.

   d. Less than 3 miles.

2. Turbulence or "chop":

   a. None.

   b. Light.

   c. Moderate.

   d. Severe.

3. Wind:

   a. Less than 10 knots.

   b. 10-20 knots; gusts greater than 5 knots.

   c. 21-30 knots; gusts greater than 10 knots.

   d. Greater than 30 knots; gusts greater than 15 knots.

4. Precipitation:

   a. None.

   b. Light rain.

   c. Moderate rain.

   d. Heavy rain, snow, or ice of any amount.

The remainder of the questions on this form are to evaluate levels of cockpit workload, fatigue, and contributing factors.

5. Place a mark on each of the following scales to indicate the amount of physical and mental work you performed during the preceding flight period.

Physical

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|
| Light | | | Moderate | | | Heavy | | Aircraft Uncontrollable |

Mental

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|
| Bored | | Light | | Moderate | | Intense | | Overload |

6. Rate your level of fatigue (circle correct response).

   a. Feel good; could fly again immediately.

   b. Slightly tired; could fly again in 30 minutes to an hour.

   c. Moderately tired; could fly again in 4-5 hours.

   d. Severely tired; could fly again in 8-10 hours after a period of sleep.

   e. Exhausted; could not fly again within 24 hours.

7. Did the extra life-supported equipment you were wearing impair your concentration or flying ability?

   a. None.

   b. Slightly.

   c. Seriously.

   d. Does not apply.

8. Grade your last flight period.

   a. Superior.

   b. Competent.

   c. Weak.

   d. Unsatisfactory.

9. Place a mark on a scale of 0-8 to indicate the amount each of the following contributed to your level of fatigue (or poor flying if you circled a 3 or 4 on question #8).

a. Time at flight controls.

0 1 2 3 4 5 6 7 8

b. Mission conditions (weather, etc.).

0 1 2 3 4 5 6 7 8

c. Noise and vibration.

0 1 2 3 4 5 6 7 8

d. Mission anxiety (overwater, ice, uncharted terrain).

0 1 2 3 4 5 6 7 8

e. Aircraft environment (temperature, lighting, odors).

0 1 2 3 4 5 6 7 8

f. Personal factors (headache, helmet fit, minor illness, personal stress, etc.).

0 1 2 3 4 5 6 7 8

g. Boredom.

0 1 2 3 4 5 6 7 8

h. Other (describe)____________________________________________

____________________________________________________________.

0 1 2 3 4 5 6 7 8

10. Comments: ____________________________________________

__________________________________________________________

_________________________________________________________.

## POST MISSION QUESTIONNAIRE

1. Assume you have just arrived in Europe in a wartime situation. With regard to a combat mission could you . . . (Circle letter of correct response.)

   a. Fly immediately?

   b. Fly after 4-5 hours rest and a meal?

   c. Fly after 8-10 hours (including a sleep period) and a meal?

   d. Fly tomorrow?

   e. Fly after 3-4 days R&R?

2. After completion of a self-deployment mission, which action do you think is most appropriate for the aircrews involved?

   a. Deployment within the theater of operations.

   b. Return to CONUS for the purpose of self-deploying additional aircraft.

3. Place a mark on each scale from 0-8 to indicate the amount each of the following contributed to your level of fatigue during the entire mission.

   a. Time at flight controls.

   0 1 2 3 4 5 6 7 8

   b. Mission conditions (weather, etc.).

   0 1 2 3 4 5 6 7 8

   c. Noise and vibration.

   0 1 2 3 4 5 6 7 8

   d. Mission anxiety.

   0 1 2 3 4 5 6 7 8

e. Aircraft environment.

0 1 2 3 4 5 6 7 8

f. Personal factors.

0 1 2 3 4 5 6 7 8

g. Circadian rhythms (frequent time zone changes and almost constant daylight).

0 1 2 3 4 5 6 7 8

h. Boredom.

0 1 2 3 4 5 6 7 8

i. Facilities at stopover points.

0 1 2 3 4 5 6 7 8

4. What do you think is the optimum amount of time to be at the flight controls during each leg of a mission such as this one? Why?

______________________________________________

______________________________________________

______________________________________________.

5. What can be done to improve mission safety?

______________________________________________

______________________________________________

6. What can be done to improve aircrew comfort on the mission?

______________________________________________

______________________________________________

7. What can be done to reduce aircrew fatigue on the mission?

8. Please comment on the adequacy, comfort and usefulness of the life support equipment.

9. Are there additional items of life support equipment which should be included on the mission?

10. Are there any items of life support equipment which could be deleted safely from the mission?

11. Was the survival and first aid training adequate for the mission?

12. What additional training do you think is necessary for medical, survival and life support?

______________________________________________

______________________________________________

______________________________________________

13. Could any areas of training be reduced and not impair mission safety?

______________________________________________

______________________________________________

14. Assuming that a flight surgeon would normally not be available, what level of medical support should be carried on a self-deployment mission of 5 to 20 helicopters? (Circle letter of correct response.)

a. Trained aircrew members alone are sufficient.

b. One 91N (flight medic) for the mission.

c. One physician's assistant for the mission with one 91N per five aircraft.

d. Other (please specify) ____________________________

______________________________________________

______________________________________________

______________________________________________