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Effects on Physiology and Performance of Wearing the Aviator NBC Ensemble While Flying the UH-60 Helicopter Flight Simulator in a Controlled Heat Environment

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The physiological and performance effects of wearing U.S. Army aviator NBC individual protective equipment (IPE) were evaluated in the USAARL UH-60 research flight simulator. Sixteen male aviators flew the simulator in four test conditions: standard flight suit and cool cockpit, standard flight suit and hot cockpit, NBC IPE and cool cockpit, and NBC IPE and hot cockpit. The hot condition had a WBGT of 30.6°C, the cool 17.9°C.

Rectal temperature, mean skin temperature, and heart rate were monitored and showed significant increases for the NBC hot condition compared with the other three. There was a significant degree of dehydration in the hot NBC condition. Seven subjects failed to complete the sortie in the NBC hot condition, with a mean survival time of 298 minutes. All subjects flew for the target 6 hours in the other conditions.

Simulator flight performance showed significant impairment in the hot NBC condition. There was little evidence of a reduction in flight performance with time. Six crashes occurred in NBC IPE, one in the standard flight suit. A performance assessment (Continued)

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battery also was undertaken before, and at regular intervals during flight. The battery showed no effect of condition, though it was sensitive to increasing time on each test day. A subjective questionnaire assessment showed increasing fatigue with time, and that all conditions produced significantly more fatigue than baseline with the worse being for NBC hot.

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Preface

This study was conducted under the auspices of the Department of the Army program, the Physiological and Psychological Effects of the NBC Environment and Sustained Operations on Systems in Combat (P^2NBC^2). The study was designed to meet the P^2NBC^2 goals and objectives, and was partly funded by the P^2NBC^2 program.

Acknowledgments

The assistance given by Dr. Heber Jones and Mr. Andy Higdon in the design of the flight profile, the data capture, and reduction is gratefully acknowledged. Mr. Al Lewis and Mr. Bob Dillard provided constant help, first in designing and installing the physiological monitoring equipment used in the simulator, and then in trouble-shooting the many initial problems in using this new system. The study could not have begun without their help. Dr. Sam Shannon provided valuable assistance with and tuition for the statistical analysis.

The work of the UH-60 simulator instructor-operators, CPT Wayne Clark, CPT Tim Hartnett, CPT Jeff Haun and MWO Larry Woodrum in training and monitoring the subjects was inestimable. CPTs Clark and Hartnett further contributed by volunteering as subjects. The postflight questionnaire was designed by Dr. Richard Texeira of the Natick Research, Development, and Engineering Center, Natick, Massachusetts.

A variety of individuals were members of the study team at various times, and they performed most of the daily tasks, including instrumenting and dressing the subjects, monitoring the physiological parameters in the simulator, and collecting and processing data. They were at the front line in interacting with the subjects and maintaining morale. They did an excellent job. They were SSG Nonilon Fallaria, SGT Joe Burke, SGT George Evans, SPC Bobby Ludwick, SPC Louis Rivera, and PVT George Hulme.

Finally, the subjects themselves must be thanked for their patience and forebearance in what was a long, stressful, and frequently boring experience, which to a man they endured without complaint and with great professionalism and good humor. They were all a great tribute to their branch.

Introduction

The wearing of chemical protective clothing by aircrew increases the thermal stress imposed on them during flight in hot weather conditions. It may add an extra layer to their clothing assembly, increasing the insulation value. It impedes ventilation of the clothing by having sealed neck, wrists, and ankles, and some components, such as the mask, may be completely impermeable to perspiration. In addition, there may be extra limitations: on pulmonary function caused by increased breathing resistance, ergonomic restrictions caused by increased bulk, manual dexterity reduced by NBC gloves, and visual impairment by the mask because of reduction to the visual fields and imperfect optical materials.

Several studies have examined the physiological penalties on pilots of wearing NBC individual protective equipment (IPE). Belyavin et al. (1979) performed a laboratory simulation to measure the heat stress of wearing the United Kingdom IPE during helicopter operations at a wet bulb globe temperature (WBGT) index of 28.9°C. They derived a mathematical model which predicted deep body temperature in such conditions would exceed 38°C within 45 min of takeoff, and that it would continue to rise at 1°C/hr. A criticism of their study is that the overall rate at which the subjects worked was probably rather high in view of more recent measurements of actual pilot workload both before and during flight (Thornton, Brown, and Higenbottam, 1984).

A U.S. Army Aeromedical Research Laboratory (USAARL) study observed six UH-1 helicopter pilots wearing either the U.S. or UK NBC IPE (Knox et al., 1982) during flights with a cockpit WBGT index between 27 and 35°C. They concluded that well acclimatized individuals, who were not required to do the preflight safety inspection of their aircraft and were allowed liberal quantities of water, would not experience significant heat strain within 2 hours. Beyond that time, three subjects were withdrawn because they reached the maximum heart rate imposed for safety reasons of 140 beats per minute while wearing the U.S. ensemble. However, it was observed that these subjects tended to be less fit and overweight.

A study of the UK IPE in 1985 (Thornton, Brown, and Redman, 1985) came to similar conclusions. They performed a climatic chamber simulation of helicopter operations at a WBGT index of 26°C. No rise in deep body temperature occurred after 2 hours at a work rate equivalent to flying a helicopter, though there was a significant rise at the higher work rate of a helicopter crewchief.

Mitchell et al. (1986) studied the effects of sustained flying operations in the U.S. IPE, with and without microclimate cooling. They found that cooling was not required at a cockpit WBGT index of less than 29°C.

A study of the standard U.S. Navy NBC ensemble, which is essentially identical to the UK's, at a WBGT of 30.6°C (Kaufman et al., 1988), resulted in a mean exposure time in IPE of 155 min, compared with 219 min in standard flying clothing before voluntary or medical withdrawal.

The psychological and performance effects of wearing NBC protective clothing also have been studied widely. Hamilton, Folds, amd Simmons (1982a) reported that pilots flying in the U.S. IPE made statistically greater heading errors than while wearing their standard flight suit or the UK IPE. In a separate study the same year (Hamilton, Simmons, and Kimball, 1982), again comparing U.S. and UK ensembles, no dramatic effects on psychomotor performance were found, though pilots' abilities to recognize and react to error situations were slightly impaired.

A study of the effects of wearing the U.S. aircrew IPE for 6 hours without the addition of thermal stress, at a WBGT index of 20°C (Hamilton and Zapata, 1983) showed degradation of affect, accuracy, and reaction time. This type of laboratory study has received a certain amount of criticism in the past for the lack of relevance to the real situation which the soldier in IPE has to perform due to the artificial nature of tasks used to simulate field conditions. This adds to the argument for the use of an aircraft simulator for this study (Kobrick and Fine, 1983; Fine and Kobrick, 1987).

Methods and materials

Simulator

The USAARL UH-60 helicopter simulator is an aeromedical version of the standard UH-60 training simulator with the addition of an environmental control system (ECS) to regulate the cockpit thermal environment by specifying dry bulb temperature (T_{db}) (68-105°F) and relative humidity (RH) (50-90 percent) (Figure 1). It is also linked to a real time data acquisition system on a VAX 11/80 computer*, which can record and analyze aircraft flight parameters and pilot inputs.

*See manufacturers' list, Appendix H.

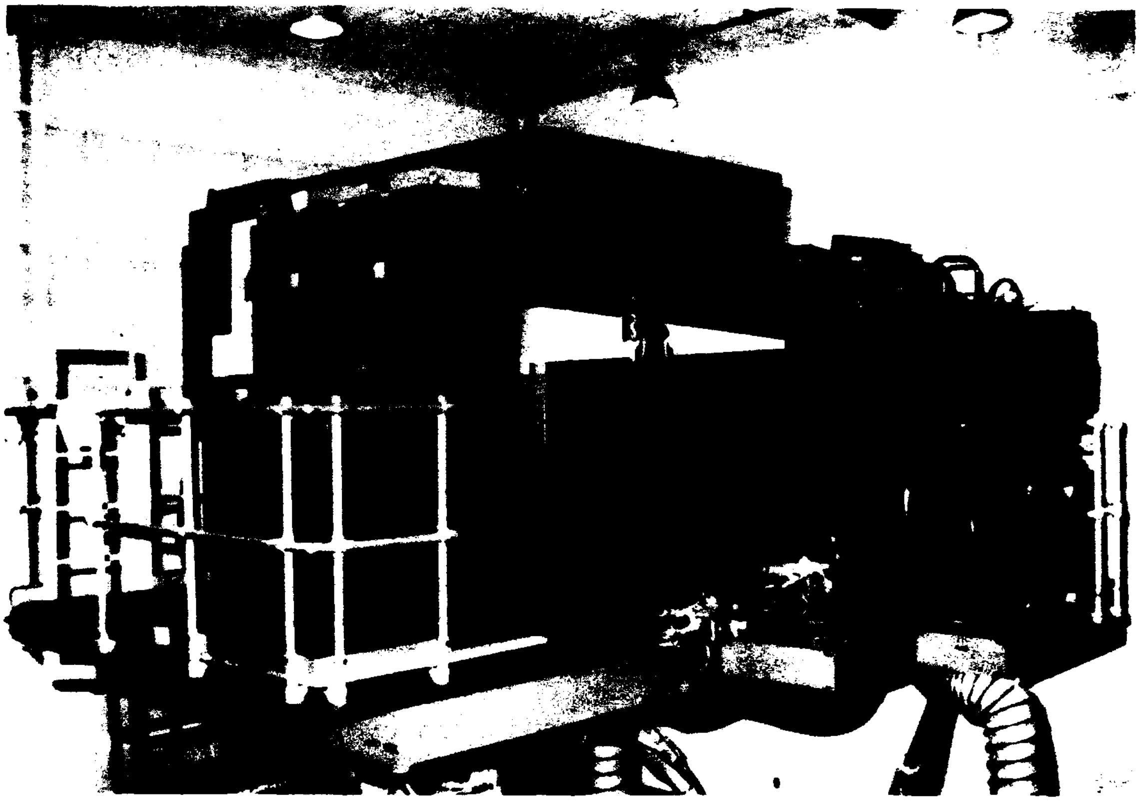

Figure 1. USAARL UH-60 research flight simulator.

The simulator is mounted on a 60-inch stroke synergistic hydraulic motion system. This provides six degrees of freedom of motion to induce acceleration cues in the lateral, longitudinal, vertical, pitch, roll, and yaw axes over a 60-degree range. The simulator uses actual earth mapping and terrain data as the basis for digital imagery generating visual scenery. Scene viewing is through a three-channel, four-window digital image generator (DIG) system. Three separate video scenes are sent to four cathode ray tube (CRT) displays. Forward looking scenery is split between two front CRTs, with scenery also presented to the left and right side window CRTs.

An onboard biomedical equipment cabinet contains a diagnostic patch panel, the ECS control panel, a 16-channel signal conditioner, and the AC/DC power distribution panels which power the biomedical research data acquisition equipment. The patch panel provides 16 input connections for biomedical signals. These connect to cabinet mounted physiological preamplifiers which can be used to boost the level of the signals.

Environmental conditions

The environmental control of the simulator as currently configured does not allow a truly accurate duplication of conditions in the cockpit of the real UH-60 aircraft due to the lack of a radiant heat source. It was, therefore, necessary to investigate the relationship between outside environmental conditions and those in the actual UH-60 helicopter cockpit, and how these can be best approximated in the simulator.

This entailed recording environmental data in the USAARL UH-60 helicopter cockpit in various flight parameters at several outside air temperatures. Cockpit WBGT was recorded with both open and closed cockpits on the ground, in the hover, and low level cruise at 100 and 500 ft above ground level (agl). These data were compared with the WBGT recorded at the point of takeoff. A more detailed study of these relationships is on-going, and will be reported separately.

The initial environmental conditions chosen were 21°C (70°F), 50 percent RH (giving an indoor WBGT of 16.8°C) for the cool condition (T1), and 40°C, 50 percent RH (WBGT 33.7°C) for the hot condition (T2). The higher temperature is the maximum achievable in the simulator, and represents the sort of level which would be present in a closed cockpit in the hover on a hot European summer's day. Flying in similar conditions in the southern United States can produce much higher temperatures, as shown in the results section. T2 was reduced after the dry runs to 35°C (95°F), 50 percent RH, (WBGT 29.4°C) for reasons explained below.

Subjects

Subjects for the study were 19 volunteer male Army aviators (UH-60 helicopter qualified). All were between the ages of 21 and 39 and in good health, as determined by a flight surgeon using a self-administered written medical history questionnaire and their medical records. The demographic data are listed in Table 1. Subjects 01 and 02 took part in the dry runs, and their results were not pooled with the others. Subject 08 left after 3 days in the study because of a domestic emergency. Subject 7 continued to participate. A variety of other pilots occupied the other seat in the cockpit to provide moral support. All subjects were asked to refrain from alcohol and caffeine-containing beverages for the duration of the study.

Table 1.
Demographic data.

No	Age	Wt(kg)	Ht(cm)	Flight hours Total	Flight hours UH-60
03	25	78.6	173	161	79
04	28	71.5	172	1200	1000
05	31	82.5	185	184	84
06	29	96.8	178	1013	850
07	27	81.1	179	700	450
09	28	100.7	176	750	500
10	26	74.8	178	1300	750
11	29	95.2	180	600	420
12	32	83.4	188	1600	95
13	36	82.3	180	1500	1300
14	31	73.2	175	1400	1250
15	23	66.7	173	1100	950
16	33	90.0	180	1200	700
17	30	80.3	183	550	80
18	28	78.9	170	950	75
19	31	85.4	181	1100	96

Apart from age and sex, the only other selection criterion was that they should not require visual correction for flight. This was applied because of the difficulties and delay that would have been encountered in providing visual correction for the M43 mask. Recruiting was done by word of mouth and advertising on posters and in Army aviation publications. The subjects were briefed verbally and in writing before participation using the letter at Appendix A.

Clothing assemblies

Two separate clothing assemblies were worn, NBC and non-NBC, as shown in Table 2.

Table 2.
Clothing assemblies.

Non-NBC
Undershirt, quarter sleeve, crew neck
Underpants
Socks
Boots
Flight suit
Flight gloves, summer
Helmet, SPH-4
SARVIP
Body armor
NBC
Undershirt, quarter sleeve, crew neck
Underpants
Socks
Boots
Flight gloves, summer
Helmet, SPH-4
SARVIP
Body armor
Gloves, chemical protective (outer only) (14 mm)
Overboots, green vinyl
AUIB
M43E-1 mask

The Aircrew Uniform Integrated Battlefield (AUIB) is under development at the Natick Research, Development, and Engineering Center (NRDEC), Natick, Massachusetts, as a two-piece garment combining both thermal and chemical protection for aviators (Figure 2). It is constructed of sage green 4.5-ounce plain weave Nomex-Kevlar/polytetrafluoroethylene (PTFE) laminated outer shell and charcoal impregnated polyurethane foam/tricot laminated liner. It is worn with the M43E-1 Aircrew Member's Protective Mask (AMPM) (Figure 3), and the Survival Armor Recovery Vest (including packets) (SARVIP) (Figure 4).

The M43E-1 mask consists of a bromobutyl facepiece with an integrated butyl hood and skirt. Overpressure is provided within the mask by a blower assembly, a battery-powered motor which blows air to the hood through two standard NBC filters. Some of the air flow is directed over the inside of the lenses to prevent

Figure 2. Aircrew Uniform Integrated Battlefield.

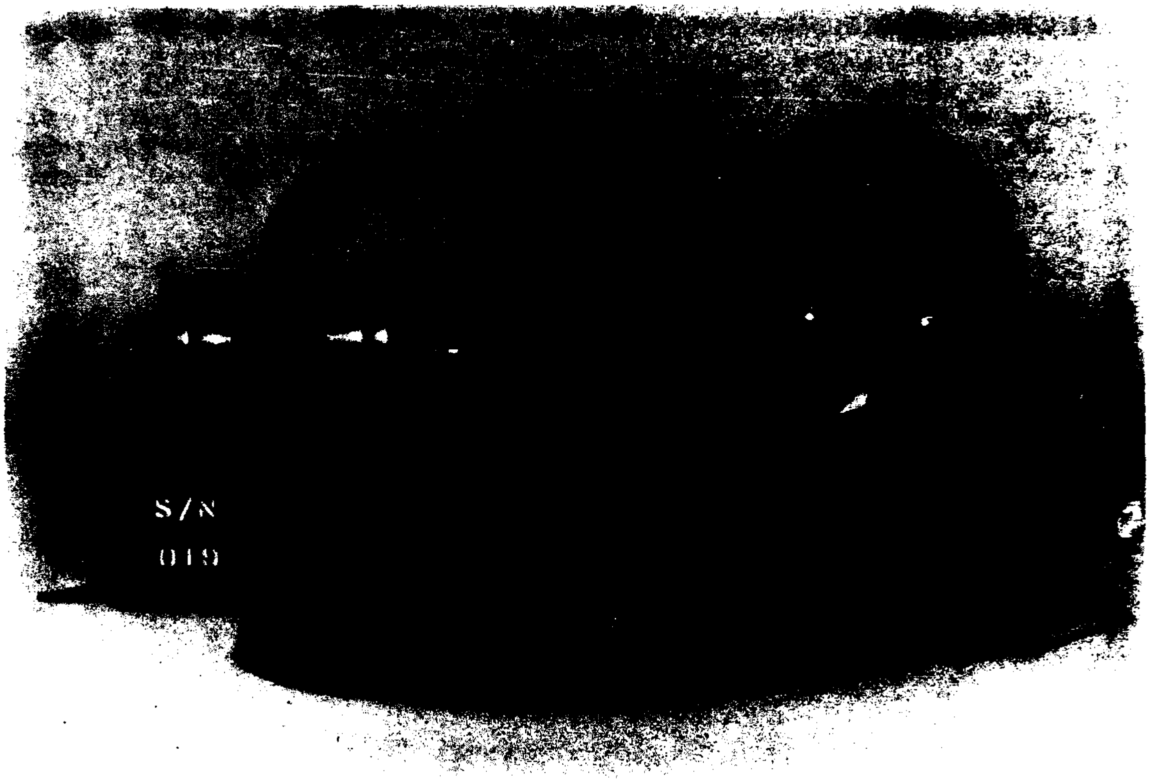

Figure 3. M43 **Aircrew Member Protective Mask.**

misting, and some over the scalp to provide cooling. The mask incorporates a microphone and drinking tube.

Physiological data

Throughout the experiment, deep body temperature, skin temperature, and heart rate were recorded at half second intervals, on the VAX computer while in the simulator, otherwise on a Squirrel 1202/42 data logger* at 1-minute intervals. The same data appeared on a meter at the medical observer's position, independent of the VAX system, in case of computer failure. The medical observer took manual recordings at 5-minute intervals to

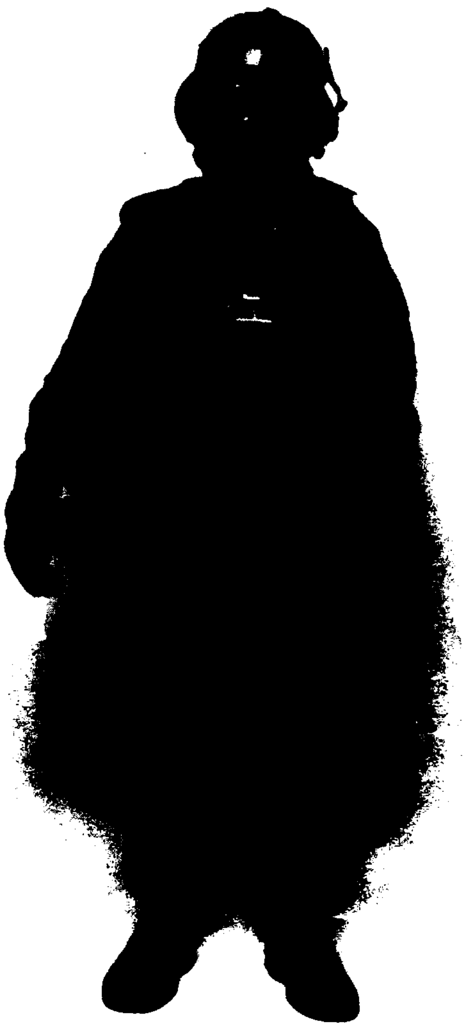

Figure 4. Complete NBC IPE.

provide data backup, and to ensure adequate monitoring of critical values.

Deep body temperature

Deep body temperature was measured using a rectal thermistor (YSI 401 style*), inserted by the subjects, 10 cm beyond the rectal sphincter.

Skin temperature

Skin temperature was measured at four sites: chest (T_{chest}), upper arm (T_{arm}), inner thigh (T_{thigh}) and outer calf (T_{leg}), using thermistors (YSI 400 series) held in position by an elastic harness. Mean skin temperature ($\bar{T}_{sk}$) was calculated after Ramanathan (1964) using the formula:

$$\bar{T}_{sk} = 0.3(T_{chest}) + 0.3(T_{arm}) + 0.2(T_{thigh}) + 0.2(T_{leg})$$

Heart rate

Heart rate was recorded from 3 ECG Ver-med electrodes* and an R wave counter (Boisig Instruments*).

Weight loss

Subjects were weighed naked, then fully clothed before each run, and clothed, then dry naked after. This enabled calculation of weight loss and evaporative sweat loss. They were allowed liberal access to drinking water at all times, through the M43 mask drinking tube, including during flight in the NBC IPE. Water canteens were weighed, and the weight drank used in the estimate of dehydration. Any urine voided between subject weighings was collected and weighed, and used likewise.

Performance assessment battery

During the copilot's nonhandling phase of each flight, flying-related tasks were minimized to leave 20 minutes available in each 2-hour sortie for performance assessment battery (PAB) testing, using the Paravant RHC-88 hand-held computer*. An additional questionnaire, the 'Fatigue Checklist,' (Pearson and Byers, 1956), which provides a subjective assessment of fatigue, was programmed into the RHC-88. The questionnaire is reproduced in Appendix C. It was necessary for the subject to remove the glove(s) from his dominant hand while undertaking these assessments, to remove any effect of reduction in manual dexterity.

During the first week, the subjects were given training sessions on each of the PAB tests in order to alleviate the learning curve associated with cognitive tests. During the actual test days, each subject received a maximum of four sessions of the performance tests: one before the flight, and one every 2 hours during the flight while the other pilot was flying the simulator.

The RHC-88 has a liquid crystal, dot matrix display with an electroluminescent panel for viewing in poor ambient light conditions. Sixteen lines of text, 42 characters per line, are available on the 5" x 2.75" screen display. The keyboard of the RHC-88 has 52 keys representing a total of 60 characters and functions. After completing each of the tests, the results were stored in the RHC-88 and later uploaded to a standard PC for further analysis.

Seven tests were administered during each of the four sessions. The tests were subject-paced, with a set number of trials administered for each test. The tests are described below.

Encode/decode (Griddle)

This test determines a person's reaction time in decoding messages. Two types of questions are presented; encode requires the subject to translate a number into four letters; decode requires the subject to translate four letters into a number. A key is given in the top of the display while the encode or decode pattern is displayed at the bottom of the screen. The subject is to decipher the code and type in his response as quickly as possible.

Six-letter search (MAST-6)

The subject is presented with 6 letters at the top of the screen and a row of 20 letters at the bottom of the screen. The subject is to determine if the top row of letters is in the bottom row of letters. If every letter is displayed in the bottom row in any order, the subject presses "S." If any letter from the top row is missing in the bottom row, the subject responds by pressing "D."

Logical reasoning

The letter pair "A B" or "B A" is presented in the top of the display with a logical statement describing the letters presented in the bottom of the display. The subject is to determine if the statement correctly describes the letters. If the statements are the same, the subject responds by pressing the letter "S;" if the statements are different, the subject presses the letter "D."

Digit recall

Nine digits are displayed in a row on the screen for 1 second. After a 3-second interval during which the screen is blank, eight of the nine digits are displayed in a different order. The subject is asked to respond by indicating which of the nine digits is missing from the second set of digits.

Serial addition/subtraction

Two numbers are displayed in sequence, followed by either a "+" or a "-" flashed after the numbers. The subject is to perform the indicated operation, either addition or subtraction. If the answer is less than zero, the subject is to add 10 to the number and input the new answer; if the answer is greater than 9, the subject is to subtract 10 from the answer and input the new answer. Each number for input will be between zero and 9, inclusive.

Matrix I

The subject is presented with an array of 14 asterisks scattered randomly on the display. After a short time, the screen is blanked, then another set of asterisks is displayed. The subject is to determine if the two sets of asterisks are either the same or different and respond by pressing either the "S" or the "D," respectively.

Wilkinson four-choice reaction time

The screen displays four boxes with one of the boxes filled. The subject presses one of four special buttons on the keyboard corresponding to the placement of the filled box. As soon as the response is made, another box is blackened and the next trial begins.

Pilot flight performance data

The simulator flight profile was designed to, as far as possible, represent a realistic tactical scenario. Within that, at regular intervals, were embedded maneuvers which had to be flown accurately to allow scoring of performance by measuring deviation from assigned values for various flight parameters. It consisted of 1 hour of tactical low level flight, followed by an hour of upper airwork. The Automatic Flight Control System (AFCS) was disabled halfway through the upper airwork to increase pilot workload. Full details are at Appendix D.

Control of the aircraft alternated between both pilots at specified intervals during flights, to allow assessment of two subjects in each flight. Should it have been necessary to withdraw one pilot for any reason, it was possible to continue assessing the other using the simulator operator as his copilot.

Aircraft preparation

During field operations of helicopters, the metabolically most demanding activities occur not during flight, but in associated activities on the ground such as preflight inspections and refuelling (Thornton and Brown, 1982). Therefore, to make this study more realistic, an initial metabolic load was devised for the subjects in the form of a simulation of preflight activities. Data are available for the average energy expenditure (370 Watts) of preflighting similar sized aircraft, so that it was possible to simulate this activity by exercising to a similar rate of work on a treadmill (4.8 km per hr, 0° slope) for 20 minutes. While there was no facility available in which this could be done with accurate climatic control, local heating was used in the USAARL cardiopulmonary laboratory, in an attempt to duplicate the simulator conditions as closely as possible (Figure 5). WBGT was recorded during this phase, together with heart rate and deep body temperature.

Questionnaire

An open-ended self-administered written questionnaire was used at the end of each day to obtain subjective information on any problems encountered, whether or not, and why performance was impaired, and any specific problems with the IPE. Because much of the questionnaire related to specific IPE problems such as comfort, fit, and integration, it was designed by and the resulting data analyzed by personnel at the Natick RD&E Center, and is included in Appendix F.

Procedure

The timetable for the 2 weeks of the study is at Appendix B, and details the order in which events occurred. The study started on the first morning with a briefing for the subjects by the principal investigator, following which they signed the consent forms and completed the initial subject questionnaire to provide the demographic data (Appendix E). The next step was a detailed instruction and practice period on the use of the RHC PAB. The subjects were briefed on the simulator flight profile by the instructor/operator (I/O), which they then flew for the

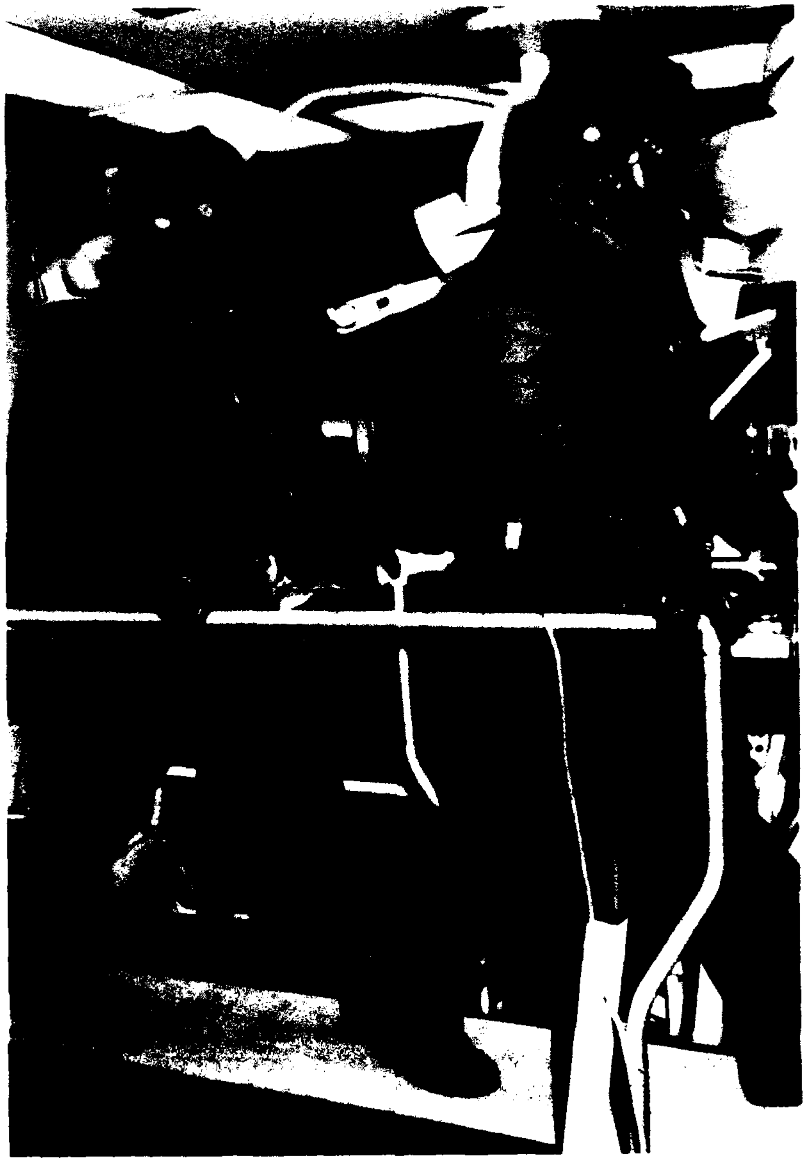

Figure 5. Treadmill exercise.

first time. After a break for lunch, the RHC PAB training was repeated, followed by a second simulator flight.

The second day followed a similar pattern of RHC PAB training and flying. The subjects were instrumented for physiological data collection for the first time immediately before the second flight of the day. The third day also followed the basic pattern of two flights interspersed with RHC PAB training sessions. There was the addition of a training period on the treadmill. The NBC ensemble was fitted and worn for the first time for the second flight of the day.

All flights on days four and five were done in NBC equipment. The two flights on the fourth day were consecutive, to build up the wearing time and tolerance gradually, as were the three flights on the final training day. The ECS was not used during the training week.

In the test week, the timetable was the same on every day. It started with instrumentation and dressing, followed by a baseline PAB. On completion of the PAB, they went straight to the treadmill for 20 minutes, and from there had a short walk inside the building to the simulator. The subjects remained in the simulator for the duration of that day's flying, up to 6 hours. If they needed to urinate during the flight, this was done into a container inside the cockpit in order to maintain constant environmental exposure and monitoring.

Each flight was of 2 hours duration, and the subjects flew the same sortie three times a day, contingent upon remaining within the withdrawal criteria. Individual flights were separated by a 10-minute 'refuelling' period, during which the pilots remained in the cockpit and in full NBC IPE, if applicable. The flight profile was identical in all sorties and on all days.

Environmental data

The simulator cockpit dry bulb temperature (T_{db}) and wet bulb temperature (T_{wb}) were measured and output to the VAX computer at 1-minute intervals. The WBGT was calculated according to the formula:

$$WBGT = 0.7T_{wb} + 0.3T_{db}$$

These data also were recorded on a Reuter Stokes RSS-217 Wibget data logger* as backup. The Reuter Stokes also was used to record the environmental data in the room housing the treadmill.

Experimental design

The experimental design is shown in Table 3. It consisted of a week of training on the experimental flight profile, initially in the standard flight suit, and then in the NBC IPE.

Flight conditions during week two were counterbalanced among subjects. There were 2 days in the standard flight suit, one, the baseline day, flown at the cool cockpit temperature (T1), and one in the hot condition (T2). There were 2 days of flying in the AUIB at both temperatures, and the final day was again in baseline conditions at T1, in order to remove the effect of any boost in performance due to end of trial euphoria, the so-called end spurt effect.

Data analysis

Flight performance data

The flight profile is divided into nine separate maneuver types. Some of the maneuvers are further subdivided, the hover maneuvers into low or high, and others into whether the AFCS was used or not. In most cases, statistically significant differences were found between the subdivisions of the divided maneuvers, necessitating separate analysis, e.g., between hover altitude error for the 40-ft hover, compared with the 10-ft hover. This is discussed further in the results.

Each maneuver is scored for up to five parameters which vary with the maneuver type. For example, navigation is scored for heading, altitude, slip, and roll while hover turn is scored for altitude only. Some maneuvers are repeated several times in each flight, and the flight is repeated three times per test day. In all, there are 69 separate flight maneuvers per test day with up to 5 relevant parameters each. Table 4 lists the maneuvers, the number of times each is repeated in each of the three flights, and the parameters associated with that maneuver.

Table 3.
Experimental design.

Week One		
Mon	am	training, flight suit, 2 hr
	pm	training, flight suit, 2 hr
Tue	am	training, flight suit, 2 hr
	pm	training, flight suit, 2 hr
Wed	am	training, flight suit, 2 hr
	pm	training, AUIB, 2 hr
Thur		training, AUIB, 4 hr
Fri		training, AUIB, 6 hr

Week Two (Counterbalanced)	
Mon	baseline, flight suit, T1
Tue	flight suit, T2
Wed	AUIB, T1
Thur	AUIB, T2
Fri	flight suit, T1

Flight performance data were recorded twice a second for 16 parameter channels, and the data were processed to produce a single root mean square (RMS) error value for each channel appropriate to each of the 9 maneuvers. The RMS values were obtained using the squared deviation from the reference value for that particular parameter. Then, these were then summed, and divided by the total number of samples. Finally, the square root was calculated, so that the units for the RMS value corresponded to those of the original parameter. The result is thus similar to the standard deviation, except that it is calculated using differences from the ideal value rather than from the mean.

Plotting the RMS error for maneuver parameters of one type sequentially throughout a test day showed no appreciable increase in error rate with time in almost all cases, as shown in the results section. This was confirmed by statistical analysis, using the methods described below. The mean error rate for each of the 55 maneuver parameter combinations, e.g., hover-heading and hover-altitude, was therefore used in the final data analysis.

Table 4.
Flight maneuver types.

Maneuver	Number	Parameters
1 Navigation	4	heading, altitude, slip, roll
2a Hover (10 ft)	1	heading, altitude
2b Hover (40 ft)	1	heading, altitude
3a Hover turn (10 ft)	1	altitude
3b Hover turn (40 ft)	1	altitude
4a Right standard turn (AFCS in)	2	rate of turn, altitude, airspeed, roll, slip
4b Right standard turn (AFCS out)	1	rate of turn, altitude, airspeed, roll, slip
5 Left descending turn	1	rate of turn, altitude, airspeed, roll, slip
6 Descent	3	heading, airspeed, roll, rate of descent, slip
7a Left standard turn (AFCS in)	1	rate of turn, altitude, airspeed, roll, slip
7b Left standard turn (AFCS out)	1	rate of turn, altitude, airspeed, roll, slip
8 Climb	2	heading, airspeed, roll, rate of climb, slip
9a Straight and level (AFCS in)	3	heading, altitude, airspeed, roll, slip
9b Straight and level (AFCS out)	1	heading, altitude, airspeed, roll, climb, slip

Analysis of variance (ANOVA) was undertaken on the RMS error values meaned for all 16 subjects, using the SAS/STAT General Linear Models (GLM) procedure and Duncan's Multiple Range Test for evaluating posteriori comparisons (Duncan, 1955). Condition and subject number both were included in the model. Repeated measures ANOVA was not appropriate because of the unequal cell size caused by subjects dropping out early on the NBC hot day. Subject number was included as a covariate in the model. This method also was used to test the relationships between maneuver subdivisions and flights, as described above. The alpha level was set at 0.05 for each comparison.

A technical problem with the simulator pedal microswitches was reported by the simulator operator at the completion of subject 19's test run. Preliminary analysis of the data indicated a 10-fold greater slip RMS error rate for him compared with the other subjects, and his slip data were consequently excluded from the analysis.

Fatigue checklist

The fatigue checklist was scored using a basic program which converted responses into a score, using the values shown in Table 5. A mean value then was calculated for each of the four administrations of the checklist in each test condition, and used in the analysis. Repeated measures analysis of variance was used to test for differences between conditions. When the sphericity assumption was violated, the Greenhouse-Geisser correction for degrees of freedom was used. Post hoc contrasts with Bonferroni adjusted probability levels to correct for alpha inflation caused by multiple comparisons were used to test for differences between conditions.

Table 5.
Fatigue checklist scores.

No	Better than	Same as	Worse than	Statement
1	(3)	(2)	(1)	very lively
2	(1)	(0)	(-1)	extremely tired
3	(2)	(1)	(0)	quite fresh
4	(2)	(1)	(0)	slightly tired
5	(3)	(2)	(1)	extremely lively
6	(2)	(1)	(0)	somewhat fresh
7	(1)	(0)	(-1)	very tired
8	(3)	(2)	(1)	very refreshed
9	(1)	(0)	(-1)	quite tired
10	(1)	(0)	(-1)	ready to drop

Performance assessment battery data

The PAB data were analyzed using a 4 x 3 analysis of variance with repeated measures on both factors. Three of the four sessions were analyzed since much of the data from session four were missing on the NBC hot day, due to early retirement from the simulator. Additionally, subjects 6 and 9 were dropped from the analysis since both only had one session of tests on the hot AUIB day. Other missing data were estimated from the cell means since the reason for the missing data was due to technical difficulties rather than the subject being pulled from the simulator. The data were analyzed using a variety of methods to compensate for the missing data.

All of the results of the statistical analyses were basically the same; therefore, the estimation of missing data with cell means was chosen to report since that method was a conservative estimate of the missing data, and most subjects were represented in the final analysis.

<u>Physiological data</u>

The physiological data on the VAX were processed by sampling them at 5-minute intervals throughout the flight, first for the pilot, then the copilot, and appending both sets of results into one file. The resulting data file was converted into an SPSS system file*, and the results were plotted using SPSS Graphics. The data were tested using regression analysis and plotting the 99 percent predicted confidence intervals. The corresponding data stored in portable data loggers were converted to Lotus files* for storage, and plotted in Lotus.

The weight loss data also were entered into Lotus files for storage and analysis. Water balance was calculated in terms of weight, percentage body weight, and rate of weight change. The latter was done in order to better compare subjects who survived a varying period of time in the NBC hot condition. It was done by dividing the total weight of, for example, dehydration by the time from starting the treadmill work to doffing the uniform. Repeated measures analysis of variance was used to test for differences in fluid balance between conditions. When the sphericity assumption was violated, the Greenhouse-Geisser correction for degrees of freedom was used. Post hoc contrasts with Bonferroni adjusted probability levels to correct for alpha inflation caused by multiple comparisons were used to test for differences between condition. Sweat loss calculations were not corrected for respiratory water loss.

Health and safety of test participants

The subjects participating in this project were all rated military pilots, having passed a recent flight physical. A briefing and questionnaire session was conducted on the first day of the trial. A written self-administered questionnaire was used to elicit personal data, significant medical history, flying experience, and exercise history. At the same time, they were fully briefed on the nature of the trial, both verbally by the principal investigator, and in written format, which they were required to read and sign. The various consent forms are reproduced at Appendix G.

The incentive for the subjects to volunteer was the opportunity to accrue up to 50 simulator flight hours which encompassed the full range of emergency maneuvers.

During all testing, both in the simulator and on the treadmill, the subjects were accompanied by a medical observer (researcher) who had a visual display of all physiological parameters, which he recorded manually every 5 minutes. This display was independent of the VAX computer, in case of any malfunction. The medical observer was fully trained in recognizing the signs and symptoms of heat illness, and in initiating emergency treatment.

The medical monitor (physician) remained within the building with a radio while the experiment was in progress, and ensured that the medical observer and primary investigator could contact her immediately at all times.

Before the trial started, all resuscitation equipment was set up in a room adjacent to the simulator bay. The room was equipped with the facility to monitor rectal temperature and ECG, and had ice packs, iced water, and cool drinks on hand. All equipment was checked daily by the medical observers. Prior arrangements were made with the Lyster Army Hospital Emergency Room (across the street from the Laboratory) to ensure immediate admission of any heat stress casualty.

A subject could be withdrawn from the experiment by the following personnel:

a. The subject at his request.
b. The medical observer if any of the criteria in Table 6 were exceeded.
c. The medical monitor.
d. The principal investigator.

Table 6.
Medical reasons for subject withdrawal.

1. Rectal temperature in excess of 39.5°C
2. Mean skin and core temperatures converge to within 0.5°C*
3. Heart rate in excess of 150 bpm for 15 minutes

*(Pandolf and Goldman, 1978)

Results

Aircraft temperature

UH-60 cockpit temperature was measured on five occasions in late summer. The mean WBGT recorded for 5 minutes of hovering was 36.4°C (SD 1.8) (98°F). The mean WBGT recorded on the ground near the aircraft for the same period was 31.7°C (SD 1.7) (89°F). A separate, more detailed study of the relationship between outdoor and cockpit temperatures is underway and will be reported separately.

Dry runs

The initial intention was to use a simulator cockpit WBGT of 33.7°C, based on the recorded aircraft temperatures. Two subjects flew in these conditions as a dry run test of procedures. In the NBC hot condition, both subjects were withdrawn by the medical observer because their deep body temperature reached the prescribed limit, the first at 33 minutes, the second at 78 minutes. Both also complained of nausea due to a strong smell of ammonia within the mask from the moment they entered the cockpit.

To use the simulator's performance measuring capability to its maximum, it was necessary for the subjects to complete at least one flight profile, which took approximately 2 hours. Therefore, it was decided to use a cooler cockpit temperature for the hot condition to produce a longer survival time, while remaining aware that it is by no means a worst case situation. After a number of trial and error sessions in the cockpit at different temperatures in the NBC IPE using laboratory personnel as subjects, a WBGT of 29.4°C was selected, with the observation that the majority of subjects should last at least 4 hours before reaching rectal temperature limits.

Flight performance

An early concern in analyzing the flight data was the validity of considering the pilot and copilot as one population for analysis of the flight performance data. They perform the same maneuvers, but the length of exposure to the various conditions is different, the pilots performing individual maneuvers some 30 minutes before the copilots. The validity was tested by analyzing the data for the two groups. There were only 6 of the 55 maneuver parameters in which there was a significant difference between the 2 groups of pilots. The differences were in the expected direction, with the copilots having larger errors than the pilots, but with such a small number showing a difference, it was decided to include all the data together. The pilots also tended to have more UH-60 experience than the copilots, which would also contribute to such a difference.

The simulator flight performance results are described separately for each of the nine maneuver types listed in Table 4, with the exception that hover and hover turn are grouped together because of the small number of parameters involved. In each case, the data used for the analyses are the RMS errors appropriate to that maneuver. The summary statistics for the data are shown in tabular form. Group numbers 1 to 4 refer to the four test conditions in the order: baseline, standard hot, NBC cool, and NBC hot. Also included as a table for each maneuver type is the maximum error and mean maximum error for each parameter before separation for hover height or AFCS.

Graphs show the RMS error for the training week and for the test week by maneuver number and meaned across all similar maneuvers. The maneuver number for the training week is concatenated from the day number and the flight of that day, i.e., 12 is the second flight on day one, 53 the third flight on day 5. Flights 11 to 31 were all flown in the standard flight suit, flights 32 to 53 in the NBC IPE. The RMS error is the mean for that maneuver for each flight.

The first test week graph in each case plots RMS error against maneuver number for the four test conditions. Points are plotted for each occurrence of the maneuver in a flight for all three flights. Maneuver number is formed from the flight number (first digit) and the number of the maneuver within that flight. Thus, 23 is the third occurrence of the maneuver in the second flight of the day. Where only one digit is shown, there was only one occurrence of that maneuver per flight. For conditions where there are five maneuver parameters, the graph for slip RMS error is omitted to save space, though it is still included in the discussion section.

The second test week graph is a bar chart of mean RMS error for each of the test conditions, grouped into subtypes of maneuver where appropriate. Significant differences between the means RMS error for different conditions are indicated on the chart by a line and asterisk, below the base axis, extending between the centers of the two different bars.

The units used in recording the various flight parameters are in Table 7.

Table 7.
Flight parameter units.

Heading	degrees
Rate of turn	degrees per minute
Altitude	feet
Airspeed	knots
Roll	degrees
Rate of climb	feet per minute
Rate of descent	feet per minute
Slip	degrees

A summary of the flight performance data statistics is shown in Table 8. There are 55 combinations of maneuver and parameter, each of which has a mean RMS error score for each of the 4 conditions. The convention used for indicating significant differences between groups is that used by SAS in their multiple comparisons testing, in which the same letter denotes means that are not significantly different. In those lines which contain both A and B, the means grouped as A are always higher than those grouped as B. The alpha value was set at 0.05. There were 21 cases in which the NBC hot value was significantly greater than for at least one of the other groups, 4 when the error in NBC cool was greater, and 2 occurrences of a baseline error value significantly greater than that for at least one of the other conditions.

Table 8.
Flight performance data statistical summary.

Maneuver	Parameter	Baseline	Condition Std Hot	NBC Cool	NBC Hot
1 Navigation	Heading	B	B	A	AB
	Altitude	B	AB	AB	A
	Slip	A	A	A	A
	Roll	A	A	A	A
2a Hover (10 ft)	Altitude	A	A	A	A
	Heading	B	AB	A	AB
2b Hover (40 ft)	Altitude	A	A	A	A
	Heading	A	A	A	A
3a Hov turn (10 ft)	Altitude	A	A	A	A
3b Hov turn (40 ft)	Altitude	B	B	AB	A
4a Right standard rate turn (AFCS in)	Rate of turn	B	B	AB	A
	Altitude	A	A	A	A
	Airspeed	A	AB	B	A
	Roll	B	B	AB	A
	Slip	A	A	A	A
4b Right standard rate turn (AFCS out)	Rate of turn	A	A	A	A
	Altitude	B	B	B	A
	Airspeed	B	B	B	A
	Roll	A	A	A	A
	Slip	A	A	A	A
5 Left descending turn (AFCS out)	Rate of turn	AB	B	AB	A
	Airspeed	A	A	A	A
	Roll	AB	B	AB	A
	Descent Rate	B	B	B	A
	Slip	A	A	A	A

Table 8 (Continued).
Flight performance data statistical summary.

Maneuver	Parameter	Baseline	Condition Std Hot	NBC Cool	NBC Hot
6 Descent (AFCS out)	Heading	A	B	B	AB
	Airspeed	B	B	B	A
	Roll	B	B	B	A
	Descent Rate	B	B	B	A
	Slip	AB	AB	B	A
7a Left standard rate turn (AFCS in)	Rate of turn	A	A	A	A
	Altitude	A	A	A	A
	Airspeed	A	A	A	A
	Roll	A	A	A	A
	Slip	A	A	A	A
7b Left standard rate turn (AFCS out)	Rate of turn	B	AB	AB	A
	Altitude	AB	B	AB	A
	Airspeed	B	B	B	A
	Roll	B	B	AB	A
	Slip	A	A	A	A
8 Climb (AFCS in)	Heading	B	B	A	AB
	Airspeed	A	A	A	A
	Roll	A	A	A	A
	Climb rate	A	A	A	A
	Slip	A	A	A	A
9a Straight and level (AFCS in)	Heading	B	B	A	B
	Altitude	A	A	A	A
	Airspeed	A	A	A	A
	Roll	A	A	A	A
	Slip	A	A	A	A
9b Straight and level (AFCS out)	Heading	A	A	A	A
	Altitude	B	B	B	A
	Airspeed	B	B	B	A
	Roll	AB	AB	B	A
	Slip	A	A	A	A

Analysis of variance was performed on the data collapsed across conditions for the effect of AFCS for those maneuvers that were performed both with and without it, (right standard rate turn, left standard rate turn, and straight and level). There was a significant difference between the 2 measures for 13 of the 15 combinations of maneuver and parameter. For 11 of them, the error was greater without the assistance of the AFCS, but in 2 cases the error was greater when the AFCS was used.

The effect of flight number also was tested using ANOVA. Collapsed across condition, there were 51 cases in which there was no significant difference among the 3 flights, leaving only 4 with some difference. In those four, only two showed an increase with flight number, and then only between flights one and two.

The same analyses were done for the NBC hot data alone on the assumption that that condition would produce the greatest performance impairment with time. There were two examples of the third flight having a significantly higher error rate than the first and second and three cases in which the third flight produced significantly greater error than the first flight. The second flight had significantly higher error rates than the first and third in two cases. There was one in which the error during the second flight was significantly greater than in the first only. In total, there were only 8 examples of a significant difference between flights, out of a possible 55 cells.

Table 9 lists the seven parameters used in scoring, and shows the number of times each gave a positive or negative result, positive indicating that there was a statistically significant difference between two of the conditions. This gives a crude indication of the sensitivity of the parameters used in the test.

Table 9.
Summary of parameter sensitivity.

Parameter	Positive	Negative
Heading	5	2
Altitude	4	6
Airspeed	5	4
Roll	5	5
Rate of turn	3	2
Vertical speed	3	1
Slip	1	10

Navigation

Navigation is scored for the four relevant parameters of heading, altitude, roll, and slip. The training data are shown in Figure 6, where RMS error is plotted against maneuver number. There is evidence of initial improvement in performance with practice for altitude and heading, which was achieved within the first one or two maneuvers. Slip error increased in the second half of the week. There was no marked reduction in performance when NBC IPE was donned for the first time at maneuver 32.

Figure 7 plots RMS error against maneuver number for the four test conditions. Collapsing across condition, there was an increase in RMS error with flight number for heading and roll. Flights two and three both had statistically significant higher error rates than flight one, though flight three was not higher than flight two. For altitude, the flight two error was significantly higher than flight one. There was no difference in the error between flights for slip.

When the NBC hot data are analyzed in isolation, the effect of flight number changes. For heading and altitude, flight two produced a significantly greater error than flights one or three. For roll, the error for flight two was significantly greater than flight one only. The fact that flight two produces a worse performance level is not entirely surprising, as most of the subjects who dropped out did so at the end of flight two, leaving the survivors, those who were coping better with the conditions anyway, to fly flight three.

Figure 8 demonstrates the mean of the RMS error for all navigation maneuvers in each condition. For heading, the cool NBC condition had a significantly higher error value than either standard hot or baseline. For altitude, hot NBC error was significantly higher than baseline. Slip and roll showed no significant difference in RMS error. The actual values for each condition are shown in Table 10. Collapsing across condition, there was a significant difference between the RMS error scores for subjects in all parameters.

Table 11 summarizes the maximum errors for each parameter.

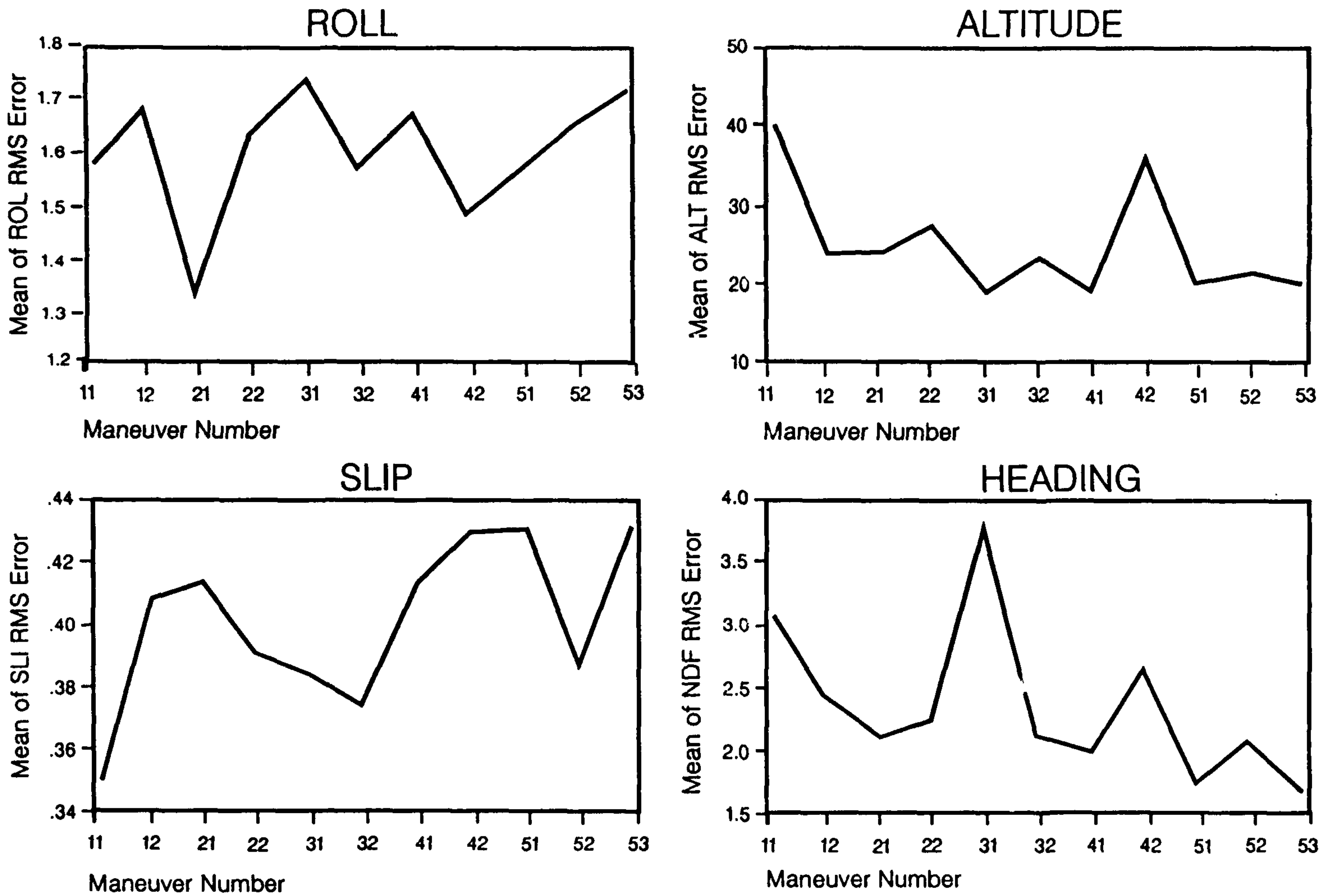

Figure 6. Mean RMS error for navigation against maneuver number, training days.

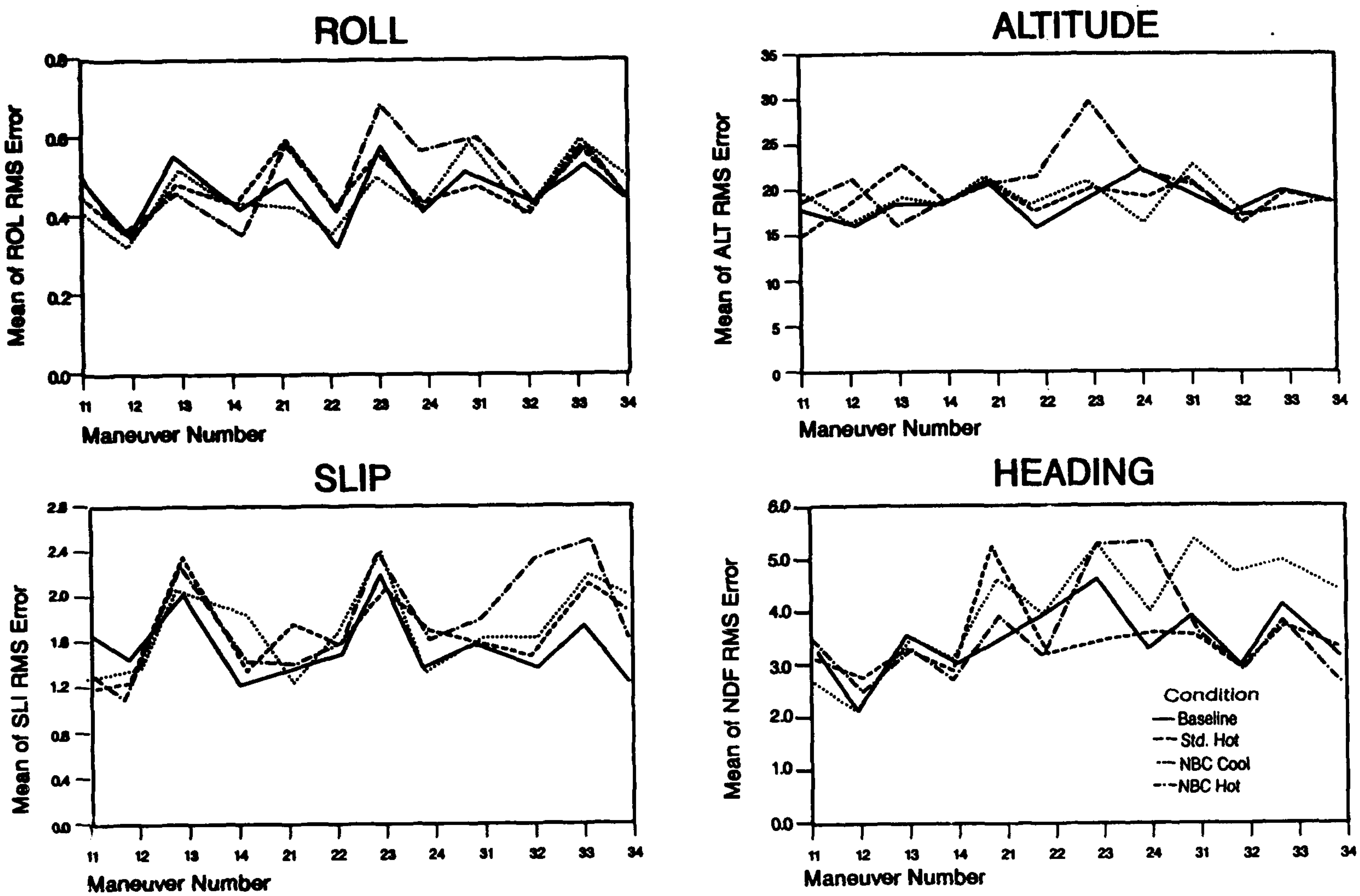

Figure 7. RMS error for navigation against maneuver number, test days.

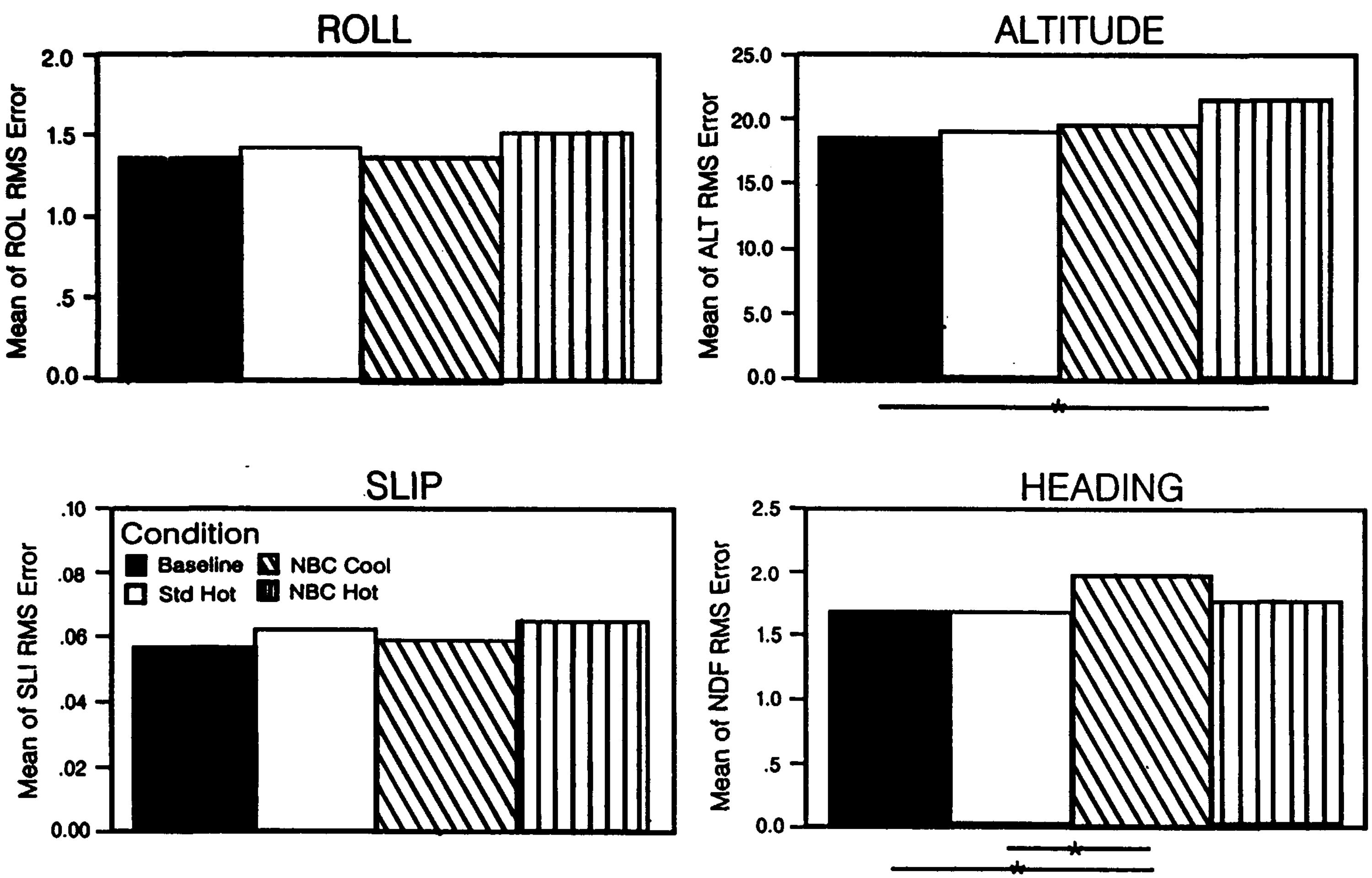

Figure 8. Mean RMS error for navigation, test days.

Table 10.
Summary statistics for navigation RMS error.

Condition	N	Mean	STD	CV
			Heading	
Condition	N	Mean	STD	CV
Baseline	191	1.7173298	1.0403667	60.5804812
Std hot	189	1.7193122	1.1181196	65.0329630
NBC cool	187	2.0254545	1.5116779	74.6340079
NBC hot	162	1.7902469	1.4043428	78.4440868
			Altitude	
Condition	N	Mean	STD	CV
Baseline	191	18.7663874	8.9322348	47.5969858
Std hot	189	19.1370899	8.7255320	45.5948735
NBC cool	187	19.4122460	9.1988509	47.3868450
NBC hot	162	20.7900000	11.8828006	57.1563278
			Slip	
Condition	N	Mean	STD	CV
Baseline	191	0.0758115	0.0865797	114.2039169
Std hot	189	0.0825926	0.1015473	122.9496791
NBC cool	187	0.0832086	0.1129819	135.7816367
NBC hot	162	0.0838889	0.0999208	119.1108589
			Roll	
Condition	N	Mean	STD	CV
Baseline	191	1.3482199	0.5031626	37.3205145
Std hot	189	1.3810582	0.6700547	48.5174868
NBC cool	187	1.3364171	0.5225172	39.0983596
NBC hot	162	1.4566049	0.8323604	57.1438666

Table 11.
Maximum navigation errors.

	Condition							
	Baseline		Std hot		NBC cool		NBC hot	
	Max error	Mean max	Max error	Mean max	Max error	Mean max	Max error	Mean max
Heading	155	6.29	27	5.40	58	5.94	80	5.83
Altitude	124	44.33	155	45.16	130	43.88	228	8.57
Slip	2	0.22	2	0.24	2	0.22	2	0.24
Roll	24	6.19	31	6.40	21	6.00	29	6.70

Hover

Hover is scored for two relevant parameters, heading and altitude. Hover turn is scored for altitude only. The training data are shown in Figure 9, where RMS error is plotted against maneuver number. The errors are plotted separately for the two heights of hovering, high (40 ft) and low (10 ft). There is evidence of initial improvement in performance with practice for all three combinations, which is achieved within the first one or two maneuvers. There was no marked reduction in performance when NBC IPE was donned for the first time at maneuver 32.

Figure 10 plots RMS error against maneuver number for the four test conditions. The data are plotted before separating into high and low hover, which is responsible for the saw-tooth effect. Collapsing across condition, there is no increase in RMS error with flight number, for all three parameters.

Figure 11 demonstrates the mean of the RMS error for all hover maneuvers in each condition. For hover heading, the cool NBC condition had a significantly higher error value than baseline. For hover turn altitude, hot NBC error was significantly higher than standard hot and baseline. Hover altitude showed no significant difference in RMS error.

Collapsing across condition, the difference in RMS error value between high and low hovering was significant in all three cases. For both altitude summaries, the error for high hover was greater than for low. For hover heading, it is, paradoxically, the other way round. The actual values for each condition are shown in Table 12. There was a significant difference between the RMS error scores for subjects in all three cases. The maximum hover errors are shown in Table 13.

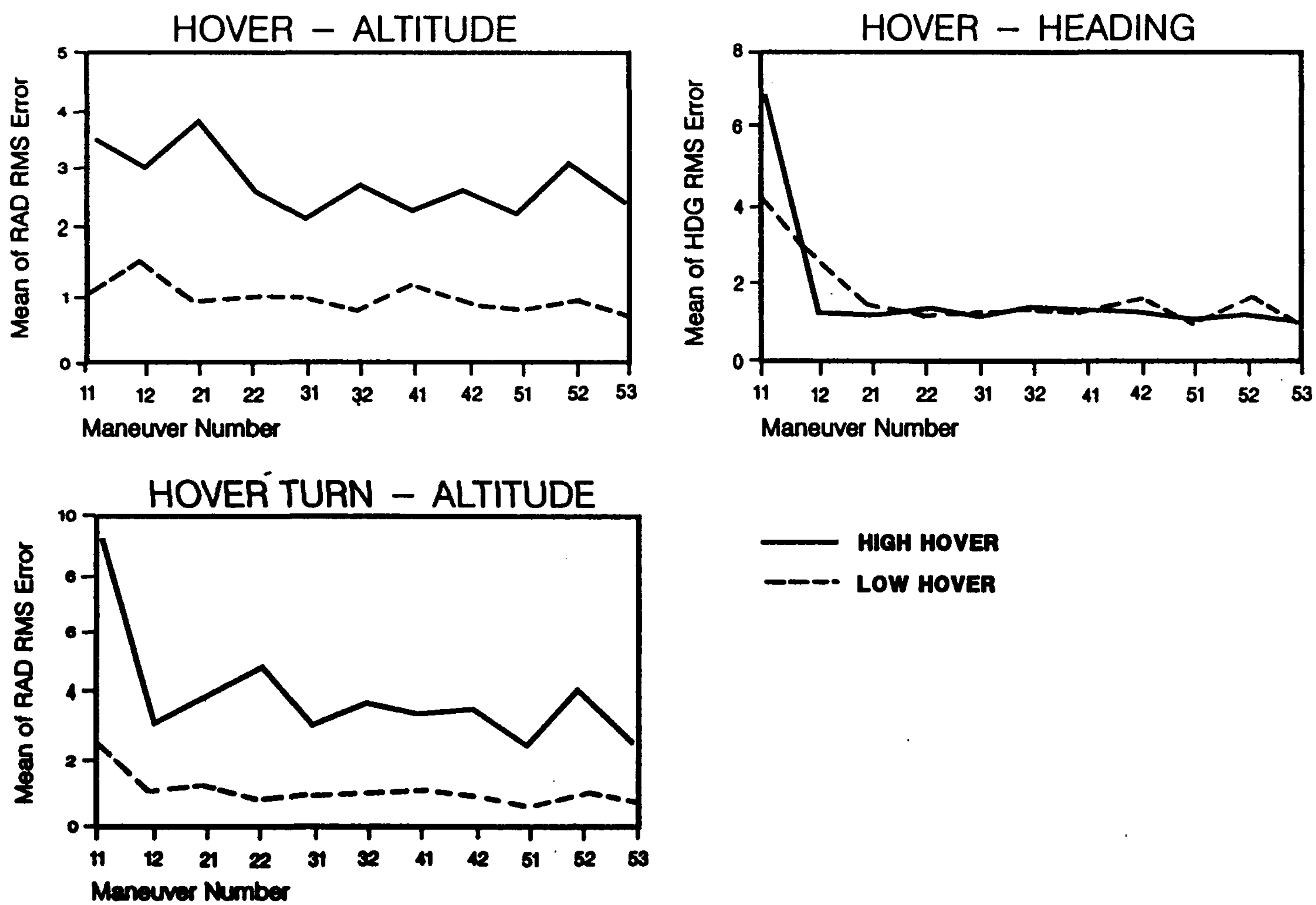

Figure 9. **Mean RMS error for hover and hover turn against maneuver number, training days.**

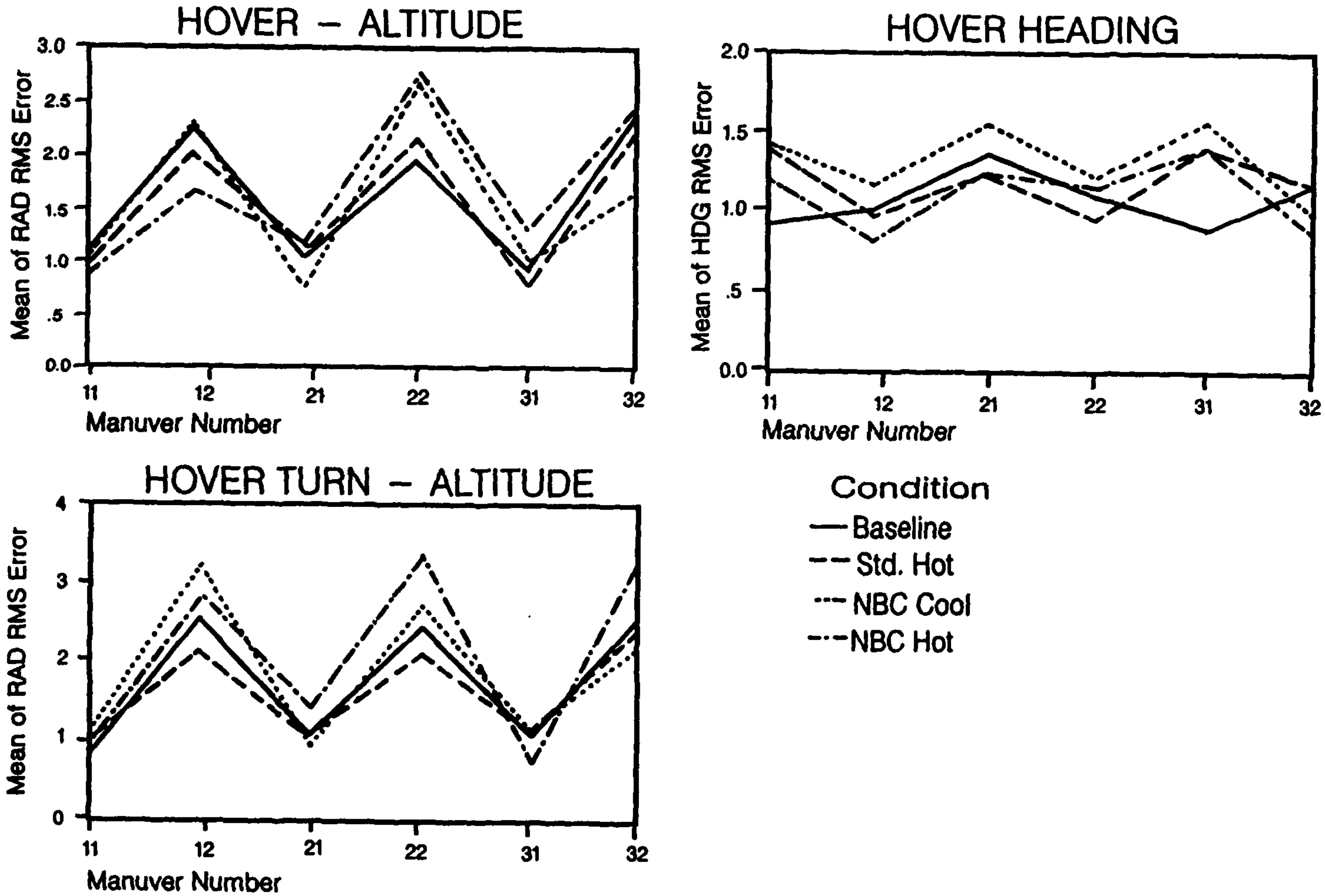

Figure 10. **RMS error for hover and hover turn against maneuver number, test days.**

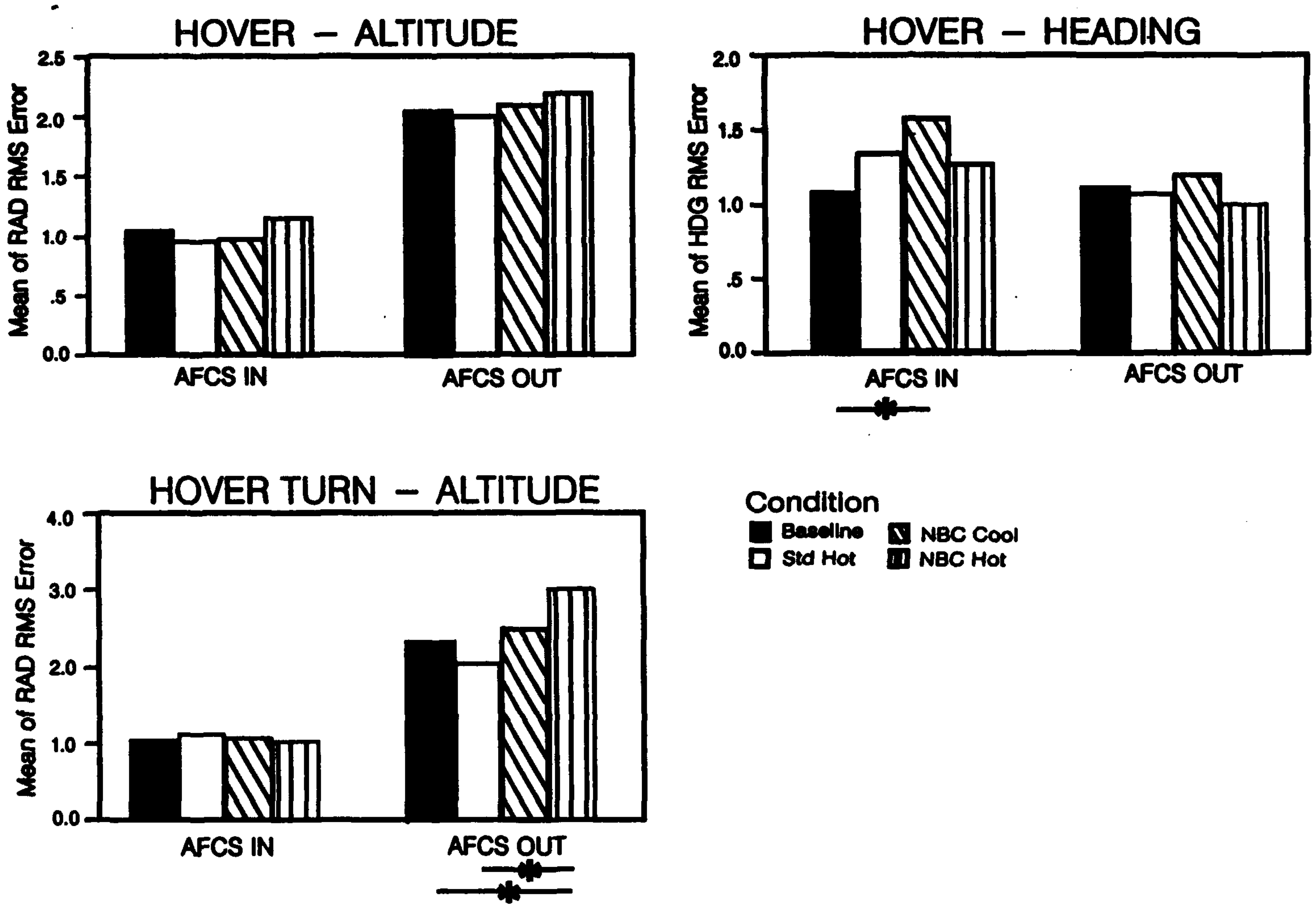

Figure 11. Mean RMS error for hover and hover turn, test days.

Table 12.
Summary statistics for hover RMS error.

Condition	N	Mean	STD	CV
		Low hover - heading		
Condition	N	Mean	STD	CV
Baseline	48	1.0643750	0.7081528	66.5322697
Std hot	48	1.3543750	1.0414186	76.8929317
NBC cool	48	1.5170833	1.5968199	105.2559136
NBC hot	40	1.2762500	0.8216016	64.3762262
		High hover - heading		
Condition	N	Mean	STD	CV
Baseline	48	1.0979167	0.5695947	51.8795930
Std hot	48	1.0350000	0.5120588	49.4742840
NBC cool	48	1.1310417	0.6615463	58.4900070
NBC hot	40	0.9597500	0.3652501	38.0567950
		Low hover - altitude		
Condition	N	Mean	STD	CV
Baseline	48	0.9918750	0.5157917	52.0016849
Std hot	48	0.9029167	0.3789288	41.9671983
NBC cool	48	0.9085417	0.4197770	46.2033835
NBC hot	40	1.0730000	0.6555334	61.0935181
		High hover - altitude		
Condition	N	Mean	STD	CV
Baseline	48	2.1966667	1.2378814	56.3527192
Std hot	48	2.1493750	1.0250281	47.6895882
NBC cool	48	2.2070833	1.3509712	61.2107026
NBC hot	40	2.2720000	1.5327538	67.4627574
		Low hover turn - altitude		
Condition	N	Mean	STD	CV
Baseline	48	1.0062500	0.5562703	55.2815255
Std hot	48	1.1100000	0.5071447	45.6887115
NBC cool	48	1.0937500	0.5831121	53.3131031
NBC hot	40	1.0837500	0.6377592	58.8474508
		High hover turn - altitude		
Condition	N	Mean	STD	CV
Baseline	48	2.5768750	1.3038424	50.5978120
Std hot	47	2.2763830	1.1719056	51.4810383
NBC cool	48	2.7547917	1.7824033	64.7019286
NBC hot	40	3.2007500	1.8830177	58.8305162

Table 13.
Maximum hover errors.

	Baseline Max error	Baseline Mean max	Std hot Max error	Std hot Mean max	NBC cool Max error	NBC cool Mean max	NBC hot Max error	NBC hot Mean max
Hover								
Altitude	14	3.32	11	3.21	12	3.15	22	3.66
Heading	7	2.17	9	2.41	15	2.51	10	2.35
Hover turn								
Altitude	17	4.14	17	3.71	40	4.62	28	5.32

Right standard rate turn

Right standard rate turn is scored for five parameters: rate of turn, altitude, airspeed, roll, and slip. The training data are shown in Figure 12, where RMS error is plotted against maneuver number. There is evidence of initial improvement in performance with practice for airspeed and altitude, which was achieved within the first one or two maneuvers. There is evidence of a reduction in performance when NBC IPE is donned for the first time at maneuver 32, though the baseline performance level was quickly reattained by the following flight.

Figure 13 plots RMS error against maneuver number for the four test conditions. The data are plotted before separating into AFCS in and AFCS out, which is responsible for the saw-tooth appearance. Collapsing across condition, there was no increase in RMS error with flight number for all five parameters. Similarly, there was no increase when the NBC hot data were examined in isolation.

Figure 14 demonstrates the mean of the RMS error for all maneuvers in each condition. For rate of turn, AFCS in, the hot NBC condition had a significantly higher error value than baseline or standard hot. There were no significant differences with the AFCS out. For altitude, AFCS out, hot NBC error was significantly higher than standard hot and NBC cool. There were no significant differences with the AFCS in. Airspeed, AFCS in, produced a significant difference for both baseline and NBC hot over NBC cool. Airspeed, AFCS out, gave a significantly higher RMS error for NBC hot compared with the other three conditions, which were remarkably consistent with each other. Roll with the AFCS in produced a significantly greater error for NBC hot compared with baseline and standard hot, and no differences with the AFCS out. For slip, there were no significant differences for any condition.

Collapsing across condition, the difference in RMS error value between AFCS in and AFCS out was significant for all parameters except airspeed. The direction of the difference varied. For rate of turn and roll, AFCS in produced the greater error, while it was the other way round for altitude and slip, with AFCS out producing the greater error. The actual values for each condition are shown in Table 13. There was a significant difference between the RMS error scores for subjects for all five parameters. Table 14 summarizes the maximum errors.

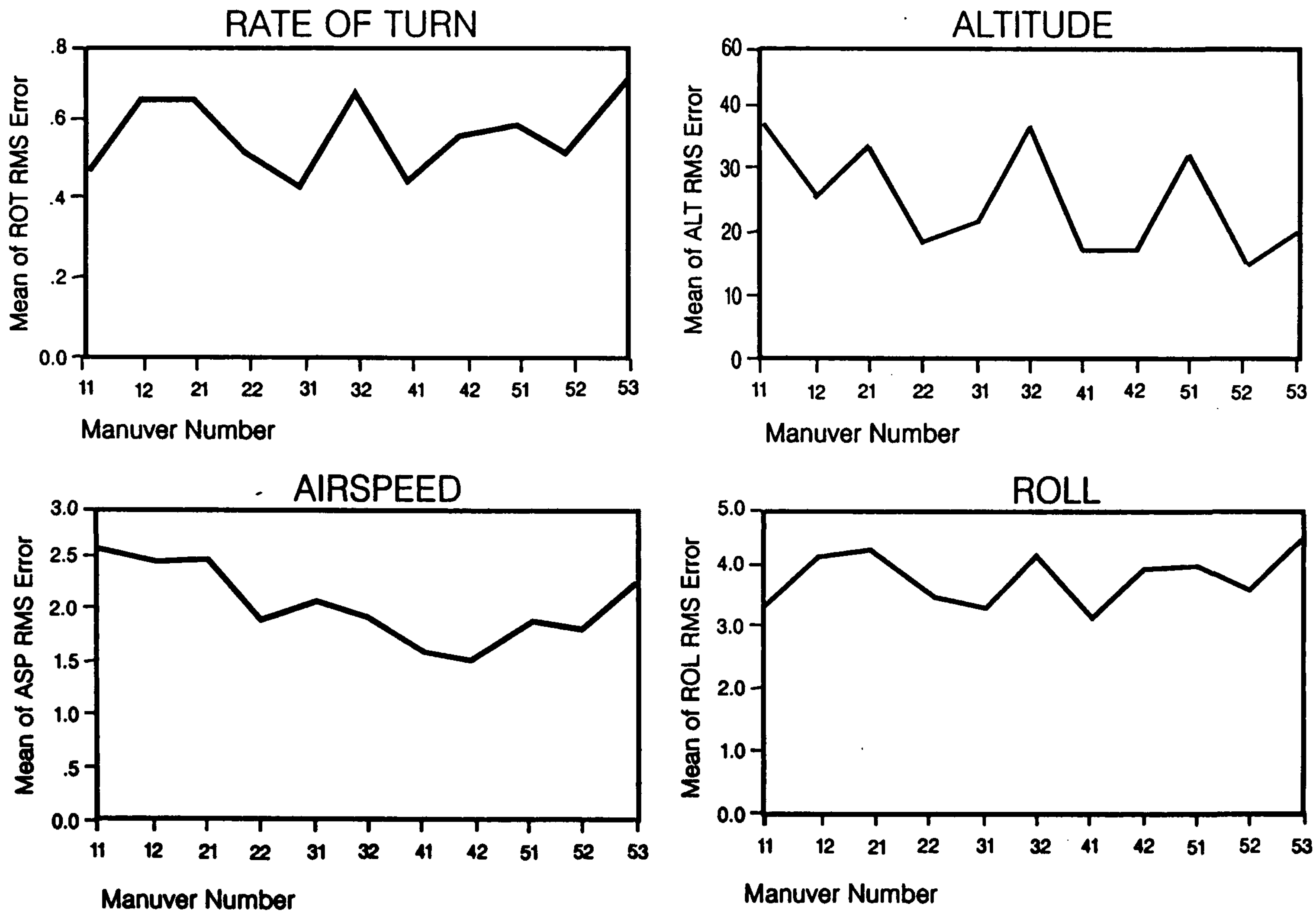

Figure 12. **Mean RMS error for right standard rate turn against maneuver number, training days.**

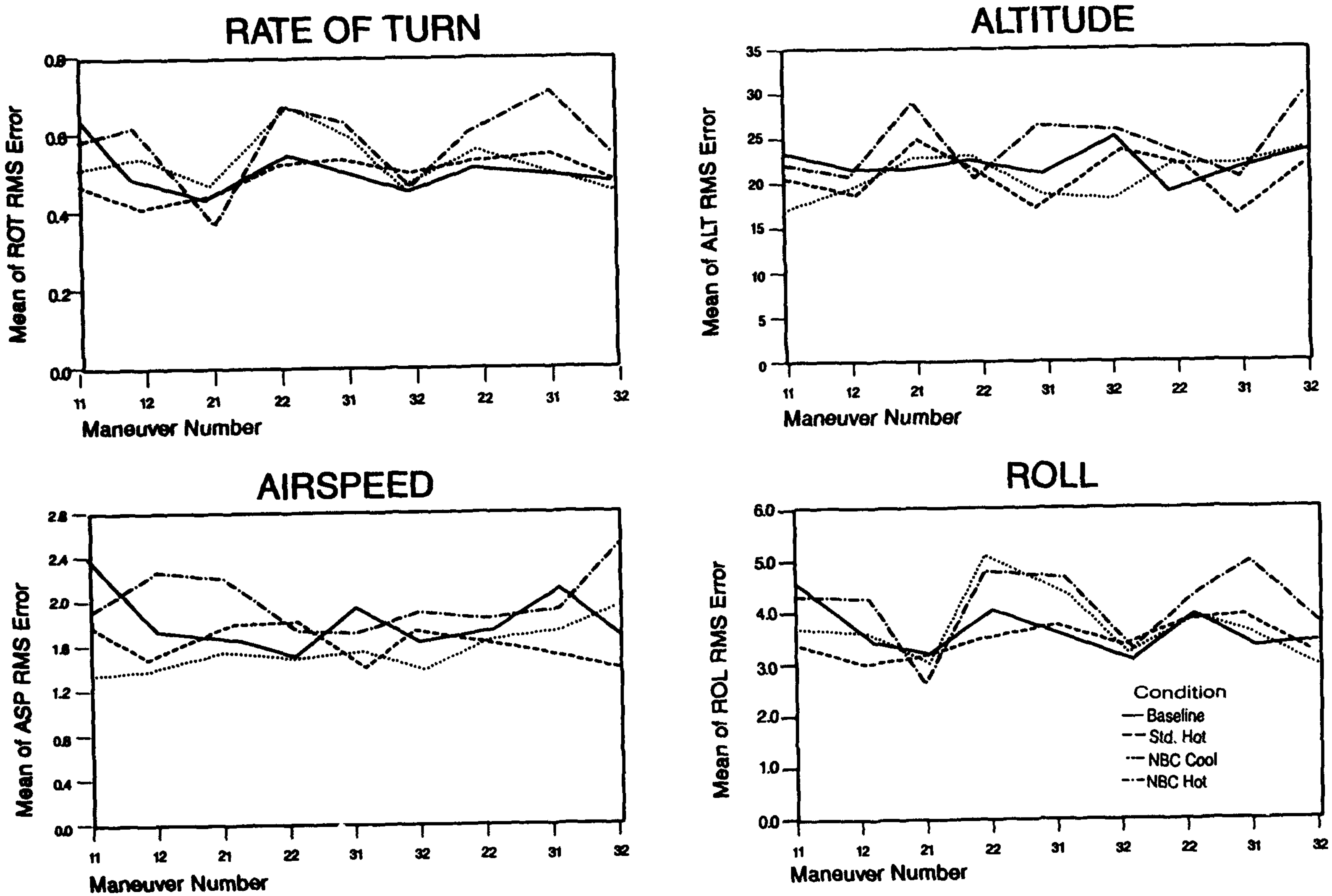

Figure 13. RMS error for right standard rate turn against maneuver number, test days.

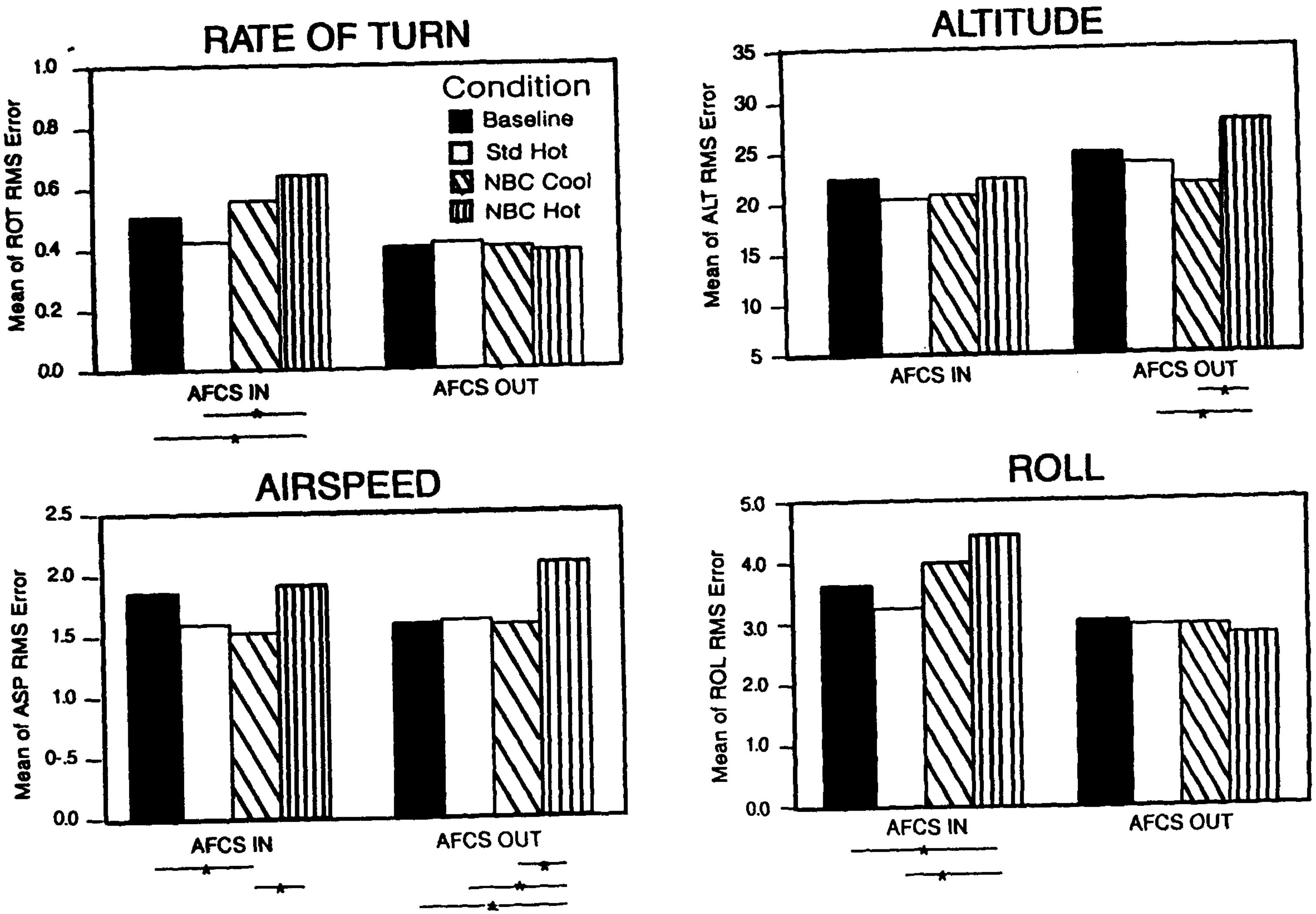

Figure 14. Mean RMS error for right standard rate turn, test days.

Table 14.
Summary statistics for right standard rate turn RMS error.

Condition	N	Mean	STD	CV
		Rate of turn - AFCS in		
Condition	N	Mean	STD	CV
Baseline	95	0.5365263	0.3416193	63.6724265
Std hot	96	0.5060417	0.3289200	64.9986035
NBC cool	94	0.5672340	0.3244860	57.2049663
NBC hot	74	0.6425676	0.3932027	61.1924331
		Rate of turn - AFCS out		
Condition	N	Mean	STD	CV
Baseline	48	0.4493750	0.1843840	41.0312184
Std hot	48	0.4633333	0.2214587	47.7968494
NBC cool	46	0.4547826	0.1931348	42.4675058
NBC hot	36	0.4466667	0.1921012	43.0077232
		Altitude - AFCS in		
Condition	N	Mean	STD	CV
Baseline	95	21.8582105	15.4311982	70.5968048
Std hot	96	19.7944792	11.4394073	57.7908983
NBC cool	94	20.6989362	12.7029365	61.3699967
NBC hot	74	22.7229730	15.3665626	67.6256694
		Altitude - AFCS out		
Condition	N	Mean	STD	CV
Baseline	48	24.4066667	13.8057520	56.5654958
Std hot	48	24.0577083	13.2446458	55.0536471
NBC cool	46	21.9360870	13.2790253	60.5350687
NBC hot	36	28.5152778	14.4364245	50.6269817
		Airspeed - AFCS in		
Condition	N	Mean	STD	CV
Baseline	95	1.9040000	1.4991021	78.7343562
Std hot	96	1.6344792	0.8963492	54.8400485
NBC cool	94	1.5603191	0.9972526	63.9133748
NBC hot	74	1.9021622	1.3928302	73.2235279
		Airspeed - AFCS out		
Condition	N	Mean	STD	CV
Baseline	48	1.6472917	0.7791860	47.3010339
Std hot	48	1.6552083	0.7489396	45.2474550
NBC cool	46	1.6467391	1.1440067	69.4710345
NBC hot	36	2.1336111	1.1057154	51.8236624

Table 14 (Continued).
Summary statistics for right standard rate turn RMS error.

Condition	N	Mean	STD	CV
		Roll - AFCS in		
Baseline	95	3.7852632	2.3130420	61.1065056
Std hot	96	3.4721875	2.3323222	67.1715505
NBC cool	94	4.0500000	2.2986232	56.7561295
NBC hot	74	4.4474324	2.7159479	61.0677711
		Roll - AFCS out		
Condition	N	Mean	STD	CV
Baseline	48	3.2229167	1.3794911	42.8025666
Std hot	48	3.1654167	1.6319587	51.5558888
NBC cool	46	3.1376087	1.4218739	45.3171187
NBC hot	36	3.1102778	1.3804895	44.3847666
		Slip - AFCS in		
Condition	N	Mean	STD	CV
Baseline	95	0.1074737	0.1254521	116.7282075
Std hot	96	0.0973958	0.1087561	111.6639911
NBC cool	94	0.1059574	0.1344149	126.8573924
NBC hot	74	0.1064865	0.1178277	110.6504166
		Slip - AFCS out		
Condition	N	Mean	STD	CV
Baseline	48	0.1389583	0.1309903	94.2659040
Std hot	48	0.1389583	0.1383526	99.5640980
NBC cool	46	0.1397826	0.1282097	91.7207871
NBC hot	36	0.1588889	0.1675330	105.4403412

Table 15.
Maximum right standard rate turn errors.

	Condition							
	Baseline		Std hot		NBC cool		NBC hot	
	Max error	Mean max	Max error	Mean max	Max error	Mean max	Max error	Mean max
Turn rate	2	6.29	2	5.40	2	0.53	2	0.58
Altitude	79	44.33	80	45.16	74	21.11	78	24.62
Airspeed	11	0.22	5	0.24	8	1.59	9	1.98
Roll	11	6.19	11	6.40	11	3.75	13	4.01
Slip	2	0.30	2	0.28	2	0.25	2	0.27

Left standard rate turn

Left standard rate turn is scored for five parameters: rate of turn, altitude, airspeed, roll, and slip. The training data are shown in Figure 15, where RMS error is plotted against maneuver number. There is evidence of initial improvement in performance with practice for airspeed and altitude which is achieved within the first one or two maneuvers. For rate of turn and roll, the RMS error increased between the first and second flight, and then improved markedly over the next two flights. There is no evidence of a reduction in performance when NBC IPE was donned for the first time at maneuver 32.

Figure 16 plots RMS error against maneuver number for the four test conditions. The data are plotted before separating into AFCS in and AFCS out, which is responsible for the sawtooth appearance. Collapsing across condition, there was no increase in RMS error with flight number, for all five parameters. When the NBC hot data were analyzed separately, rate of turn showed a significant increase for NBC flight three over flight one. For altitude, there was a significant increase for flight three over flights one and two.

Figure 17 demonstrates the mean of the RMS error for all maneuvers in each condition. For rate of turn, AFCS out, the hot NBC condition had a significantly higher error value than baseline or standard hot. There were no significant differences with the AFCS in. For altitude, AFCS out, hot NBC error was significantly higher than standard hot. There were no significant differences with the AFCS in. Airspeed, AFCS out produced a significant difference for NBC hot over all other conditions. There were no significant differences with the AFCS in. Roll with the AFCS out produced a significantly greater error for NBC hot compared with baseline and standard hot, and no differences with the AFCS in. For slip, there were no significant differences for any condition.

Collapsing across condition, the difference in RMS error value between AFCS in and AFCS out was significant for all parameters, with AFCS out always producing the higher error. The actual values for each condition are shown in Table 16. There was a significant difference between the RMS error scores for subjects for all five parameters.

Table 17 shows the maximum errors for left standard rate turn.

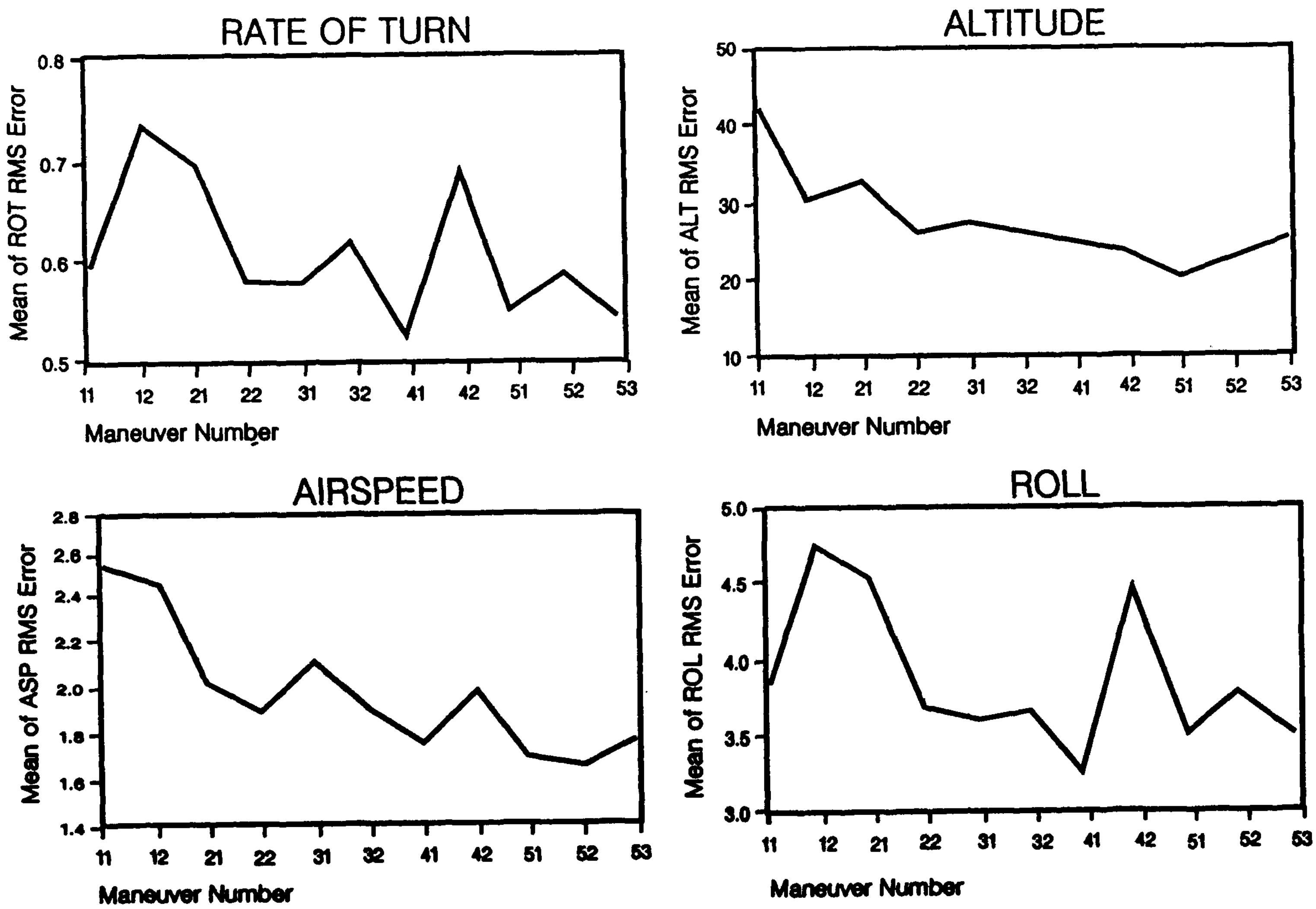

Figure 15. Mean RMS error for left standard rate turn against maneuver number, training days.

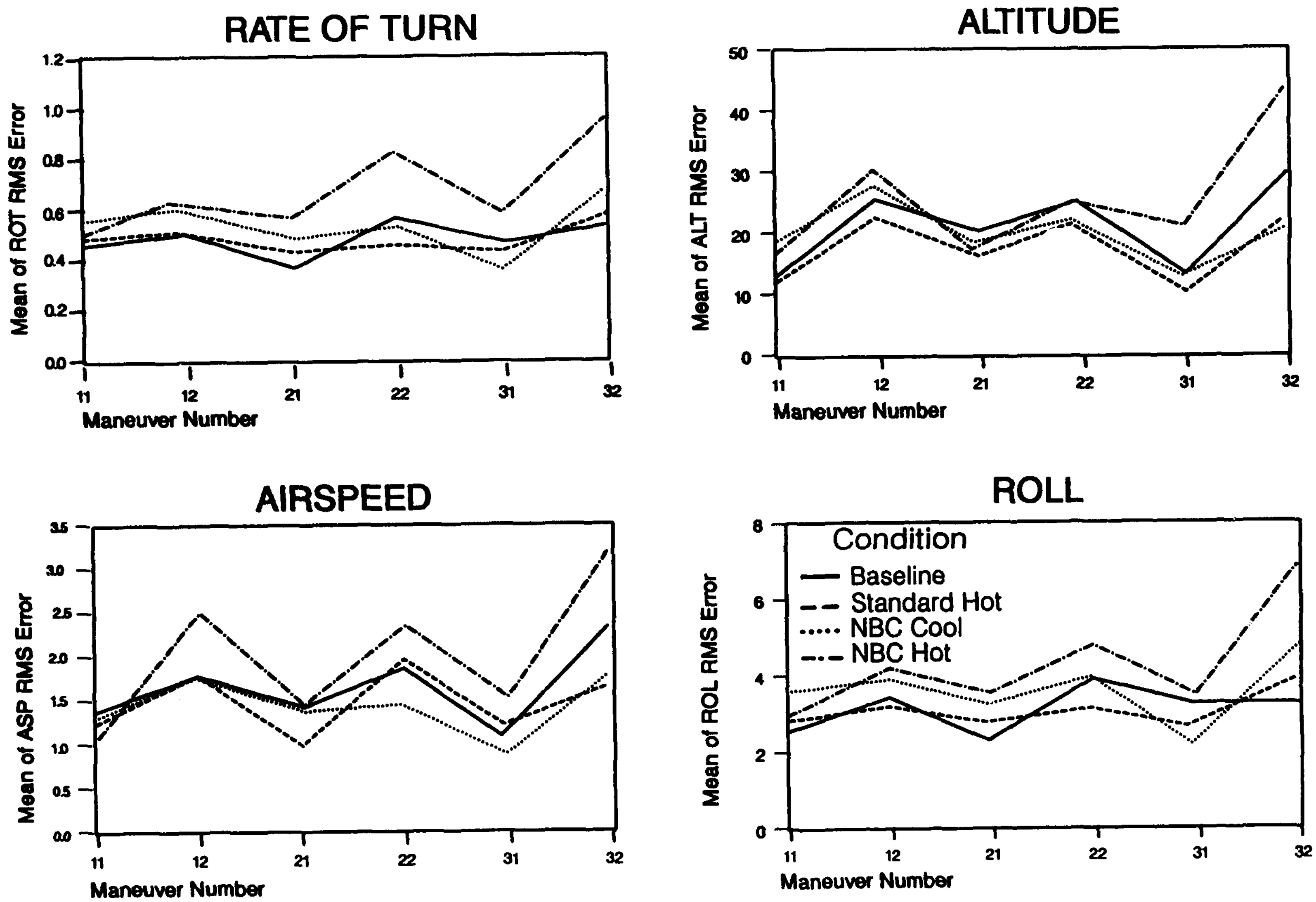

Figure 16. RMS error for left standard rate turn against maneuver number, test days.

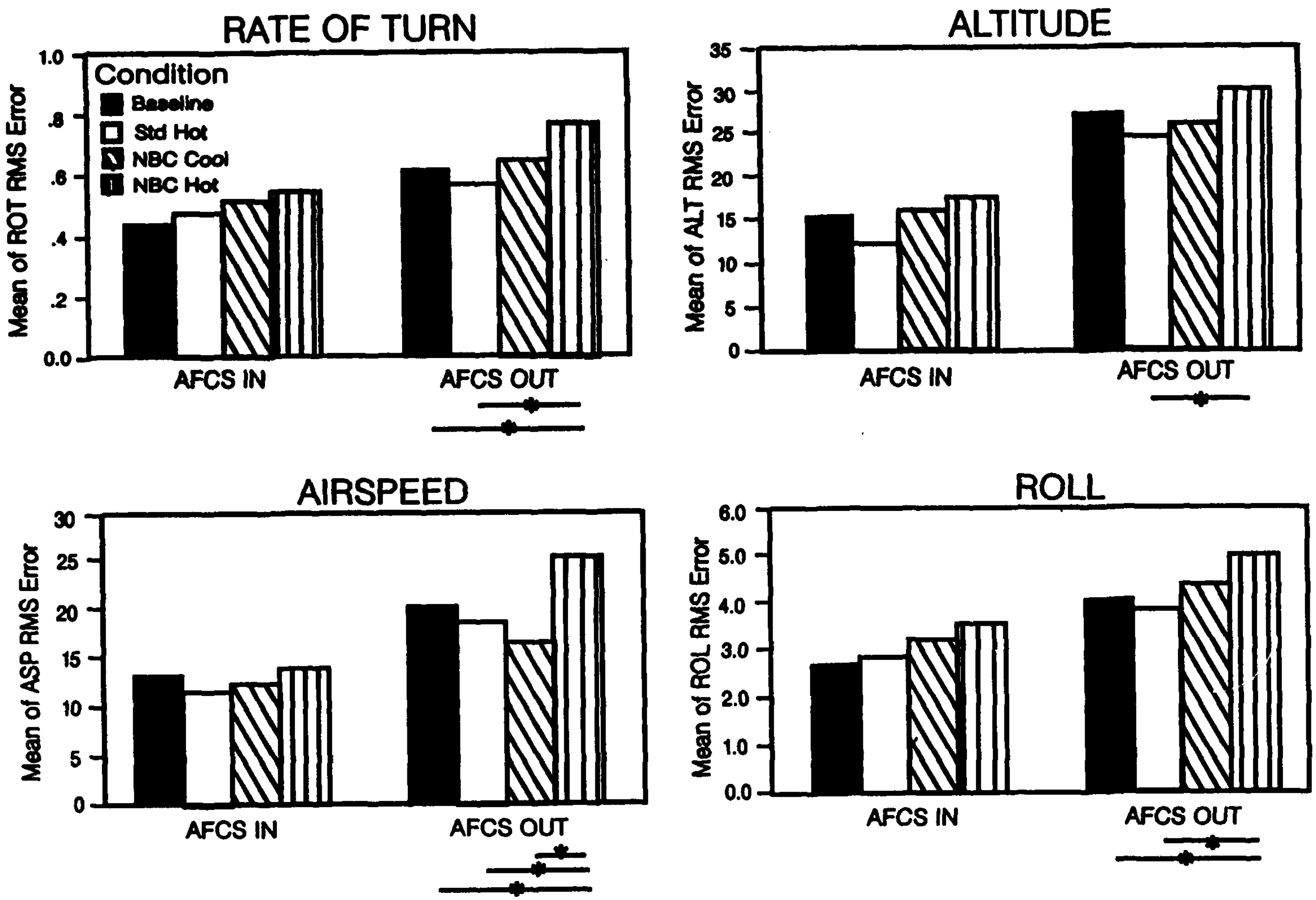

Figure 17. Mean RMS error for left standard rate turn, test days.

Table 16.
Summary statistics for left standard rate turn RMS error.

Condition	N	Mean	STD	CV
		Rate of turn - AFCS in		
Condition	N	Mean	STD	CV
Baseline	48	0.4466667	0.2236290	50.0661937
Std hot	48	0.4612500	0.3228769	70.0004037
NBC cool	47	0.4927660	0.3088738	62.6816527
NBC hot	37	0.5227027	0.2481224	47.4691210
		Rate of turn - AFCS out		
Condition	N	Mean	STD	CV
Baseline	48	0.5691667	0.2996085	52.6398521
Std hot	48	0.5433333	0.3469891	63.8630200
NBC cool	46	0.6286957	0.3169129	50.4080069
NBC hot	36	0.7641667	0.5109899	66.8689120
		Altitude - AFCS in		
Condition	N	Mean	STD	CV
Baseline	48	15.9737500	12.6305081	79.0704004
Std hot	48	13.4327083	7.0976630	52.8386594
NBC cool	47	17.0165957	11.9541023	70.2496697
NBC hot	37	17.5229730	8.8865785	50.7138742
		Altitude - AFCS out		
Condition	N	Mean	STD	CV
Baseline	48	26.6408333	19.0154828	71.3772072
Std hot	48	23.2502083	14.2911247	61.4666522
NBC cool	46	24.6565217	14.2092186	57.6286420
NBC hot	36	30.5783333	21.2487493	69.4895600
		Airspeed - AFCS in		
Condition	N	Mean	STD	CV
Baseline	48	1.2302083	0.6895990	56.0554639
Std hot	48	1.1312500	0.4675041	41.3263314
NBC cool	47	1.1714894	0.4749324	40.5409052
NBC hot	37	1.2597297	0.6106485	48.4745645
		Airspeed - AFCS out		
Condition	N	Mean	STD	CV
Baseline	48	2.0160417	0.9938722	49.2981954
Std hot	48	1.8964583	0.7405734	39.0503361
NBC cool	46	1.7380435	0.7352267	42.3019743
NBC hot	36	2.5197222	1.4372066	57.0382948

Table 16 (Continued).
Summary statistics for left standard rate turn RMS error.

Condition	N	Mean	STD	CV
		Roll - AFCS in		
Baseline	48	2.7629167	1.6422299	59.4382703
Std hot	48	2.7875000	2.2800471	81.7954126
NBC cool	47	3.0525532	2.2699554	74.3625187
NBC hot	37	3.2113514	1.8848742	58.6941145
		Roll - AFCS out		
Condition	N	Mean	STD	CV
Baseline	48	3.7577083	2.0947790	55.7461829
Std hot	48	3.5279167	2.4874570	70.5078165
NBC cool	46	4.2302174	2.2332413	52.7925890
NBC hot	36	4.9986111	3.4684135	69.3875446
		Slip - AFCS in		
Condition	N	Mean	STD	CV
Baseline	48	0.0610417	0.0705070	115.5062926
Std hot	48	0.0639583	0.0652243	101.9793817
NBC cool	47	0.0668085	0.0897123	134.2826741
NBC hot	37	0.0662162	0.0895778	135.2806911
		Slip - AFCS out		
Condition	N	Mean	STD	CV
Baseline	48	0.1639583	0.2093835	127.7053040
Std hot	48	0.1516667	0.2162478	142.5809816
NBC cool	46	0.1606522	0.2613674	162.6914575
NBC hot	36	0.1469444	0.1859926	126.5734263

Table 17.
Maximum left standard rate turn errors.

	Condition							
	Baseline		Std hot		NBC cool		NBC hot	
	Max error	Mean max	Max error	Mean max	Max error	Mean max	Max error	Mean max
Turn rate	4	2.09	5	1.90	4	2.22	6	2.41
Altitude	141	39.70	105	35.66	122	38.47	223	46.72
Airspeed	10	3.36	7	3.13	8	3.02	12	3.71
Roll	30	15.05	34	13.70	27	15.94	61	17.23
Slip	2	0.19	2	0.18	2	0.19	2	0.21

Left descending turn

Left descending turn is scored for five parameters: rate of turn, airspeed, roll, rate of descent, and slip. The training data are shown in Figure 18, where RMS error is plotted against maneuver number. There is evidence of initial improvement in performance with practice for all parameters between the first two maneuvers. There is no evidence of a reduction in performance when NBC IPE was donned for the first time at maneuver 32.

Figure 19 plots RMS error against maneuver number for the four test conditions. There was only one left descending turn flown per flight, and it was done after the AFCS had been failed. Collapsing across condition, for rate of descent, the error for the second flight was significantly higher than for the third flight. There was no significant difference between the first flight and either of the other two. For the other four parameters, there was no increase in RMS error with flight number. When the NBC hot data were analyzed separately, for rate of turn and roll, there was a significantly greater error for flight three compared with flight one.

Figure 20 demonstrates the mean of the RMS error for all maneuvers in each condition. For rate of turn, the hot NBC condition had a significantly higher error value than standard hot. Airspeed produced no significant differences. Roll produced a significantly greater error for NBC hot compared with standard hot. Rate of descent showed a significantly greater error for NBC hot than all other conditions. For slip, there were no significant differences for any condition.

The actual values for each condition are shown in Table 18. There was a significant difference between the RMS error scores for subjects for all five parameters. The maximum error values are in Table 19.

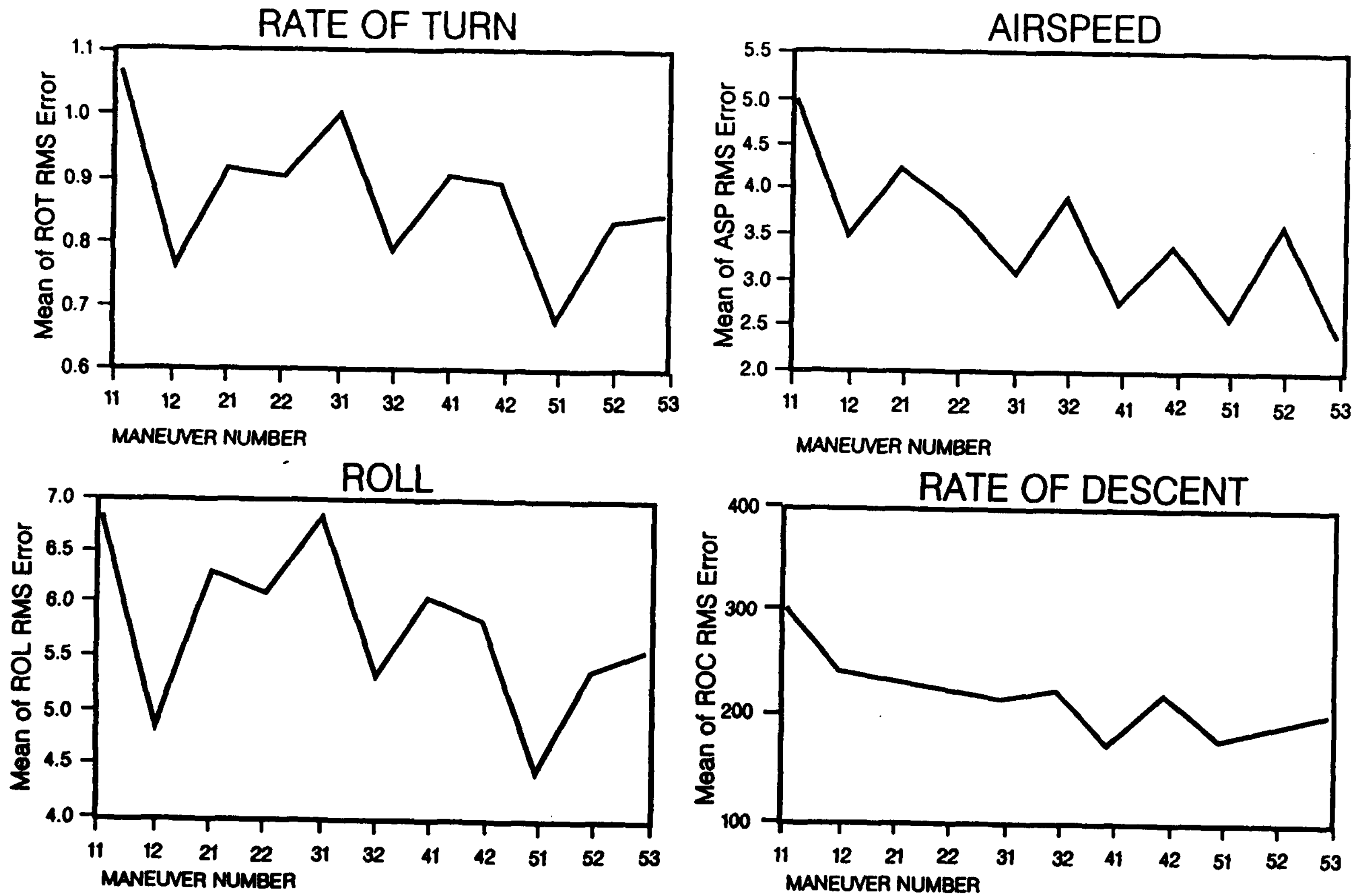

Figure 18. Mean RMS error for left descending turn against maneuver number, training days.

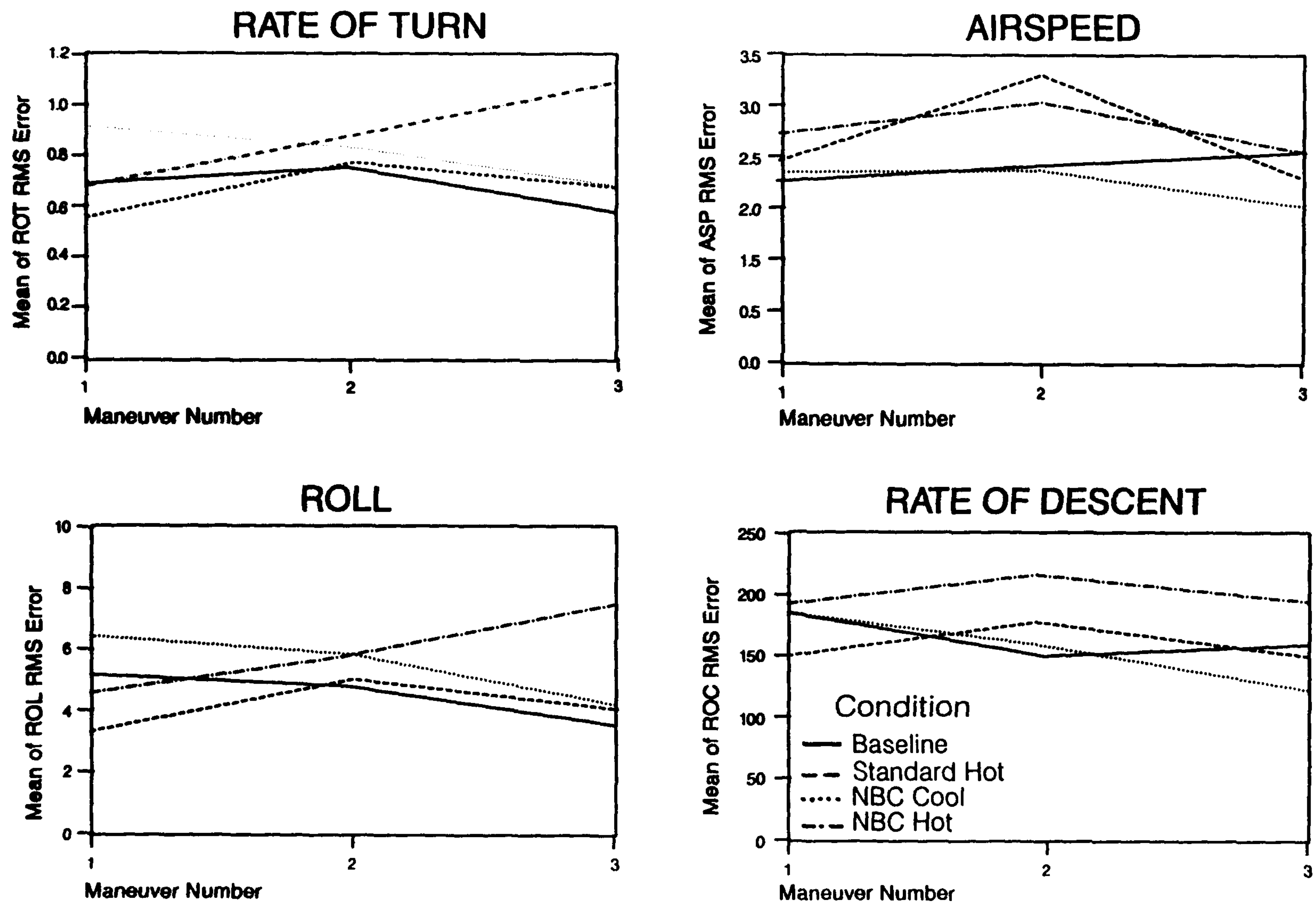

Figure 19. RMS error for left descending turn against maneuver number, test days.

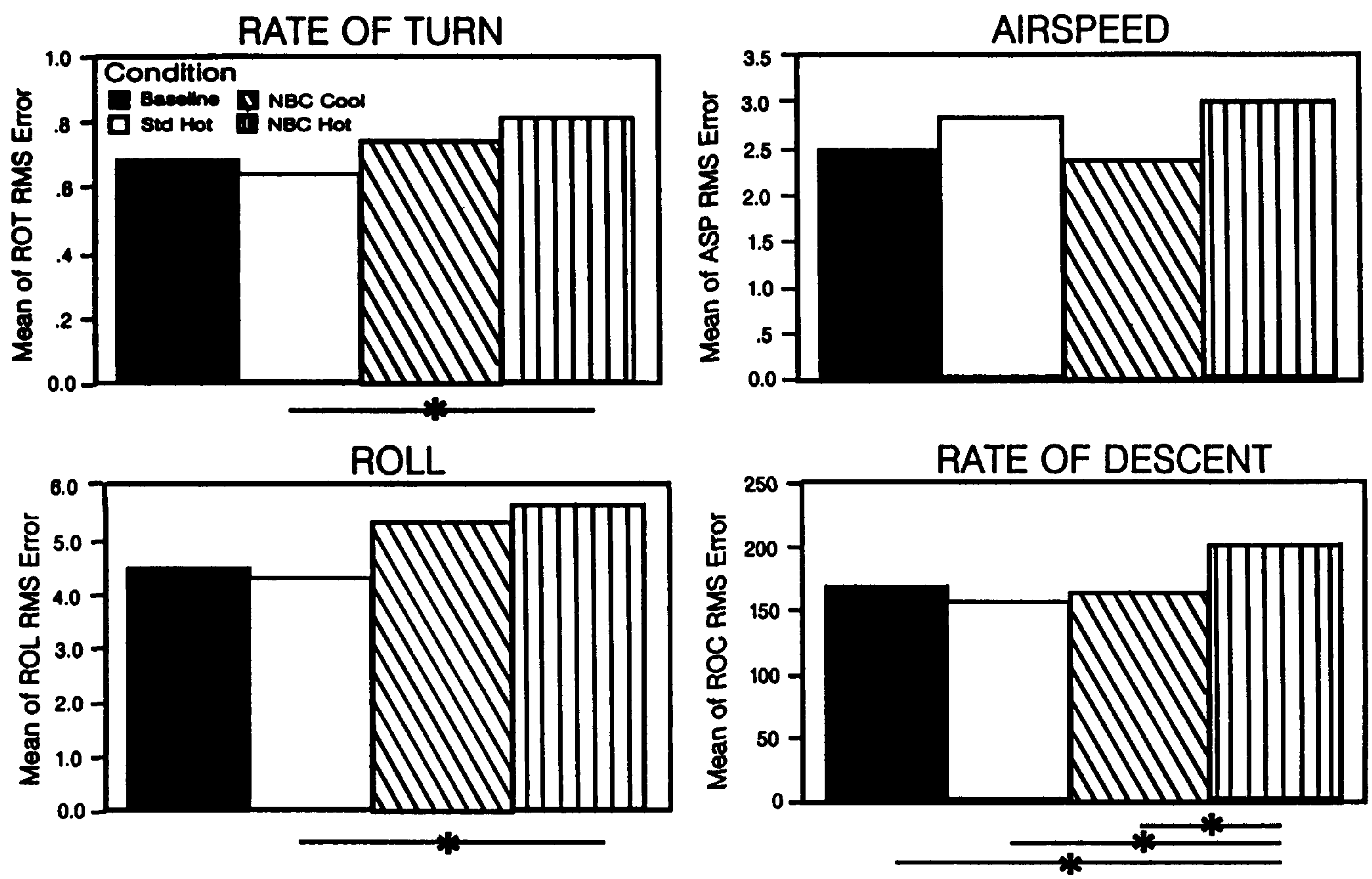

Figure 20. Mean RMS error for left descending turn, test days.

Table 18.
Summary statistics for left descending turn RMS error.

Condition	N	Mean	STD	CV
		Rate of turn		
Condition	N	Mean	STD	CV
Baseline	48	0.6662500	0.3456885	51.8857020
Std hot	48	0.6443750	0.3536491	54.8824986
NBC cool	47	0.7921277	0.4565558	57.6366444
NBC hot	37	0.8308108	0.4217317	50.7614647
		Airspeed		
Condition	N	Mean	STD	CV
Baseline	48	2.5018750	1.3998125	55.9505385
Std hot	48	2.7750000	1.5497618	55.8472728
NBC cool	47	2.3582979	1.1250339	47.7053371
NBC hot	37	2.8367568	1.7440391	61.4800383
		Roll		
Condition	N	Mean	STD	CV
Baseline	48	4.3989583	2.4556849	55.8242361
Std hot	48	4.2502083	2.5147044	59.1666151
NBC cool	47	5.3325532	3.2742802	61.4017351
NBC hot	37	5.5340541	3.2441618	58.6217949
		Rate of descent		
Condition	N	Mean	STD	CV
Baseline	48	169.0412500	71.7165221	42.4254566
Std hot	48	162.4985417	61.0097551	37.5448016
NBC cool	47	164.0646809	68.4517079	41.7223911
NBC hot	37	198.0135135	78.1703949	39.4773031
		Slip		
Condition	N	Mean	STD	CV
Baseline	48	0.1727083	0.2341734	135.5889513
Std hot	48	0.1545833	0.2085712	134.9247731
NBC cool	47	0.1642553	0.2374479	144.5602415
NBC hot	37	0.2132432	0.3581670	167.9617331

Table 19.
Maximum left descending turn errors.

	Baseline Max error	Baseline Mean max	Std hot Max error	Std hot Mean max	NBC cool Max error	NBC cool Mean max	NBC hot Max error	NBC hot Mean max
Turn rate	4	2.17	6	2.21	4	2.43	4	2.63
Desc rate	724	392.59	1039	381.63	734	385.85	1108	483.00
Airspeed	9	4.42	17	2.85	9	4.25	14	5.18
Roll	27	14.87	40	7.52	23	16.55	28	17.41
Slip	2	0.27	2	0.36	2	0.25	2	0.31

Descent

Descent is scored for five parameters: heading, airspeed, roll, rate of descent, and slip. The training data are shown in Figure 21, where RMS error is plotted against maneuver number. There is evidence of initial improvement in performance with practice for airspeed and rate of descent for the first two maneuvers. Performance at roll appears to have deteriorated steadily for the first half of the week. There is no consistent evidence of a reduction in performance when NBC IPE was donned for the first time at maneuver 32.

Figure 22 plots RMS error against maneuver number for the four test conditions. Descent was flown only after the AFCS had been failed. Collapsing across condition, there was no increase in RMS error with flight number for all five parameters. The same findings applied when the hot NBC data were considered in isolation.

Figure 23 demonstrates the mean of the RMS error for all maneuvers in each condition. For heading, the baseline condition had a significantly higher error value than standard hot and NBC cool. For airspeed, roll, and rate of descent, the NBC hot condition had a significantly greater error than any of the other conditions. For slip, there were no significant differences for any condition.

The actual values for each condition are shown in Table 20. There was a significant difference between the RMS error scores for subjects for all five parameters. The maximum errors are in Table 21.

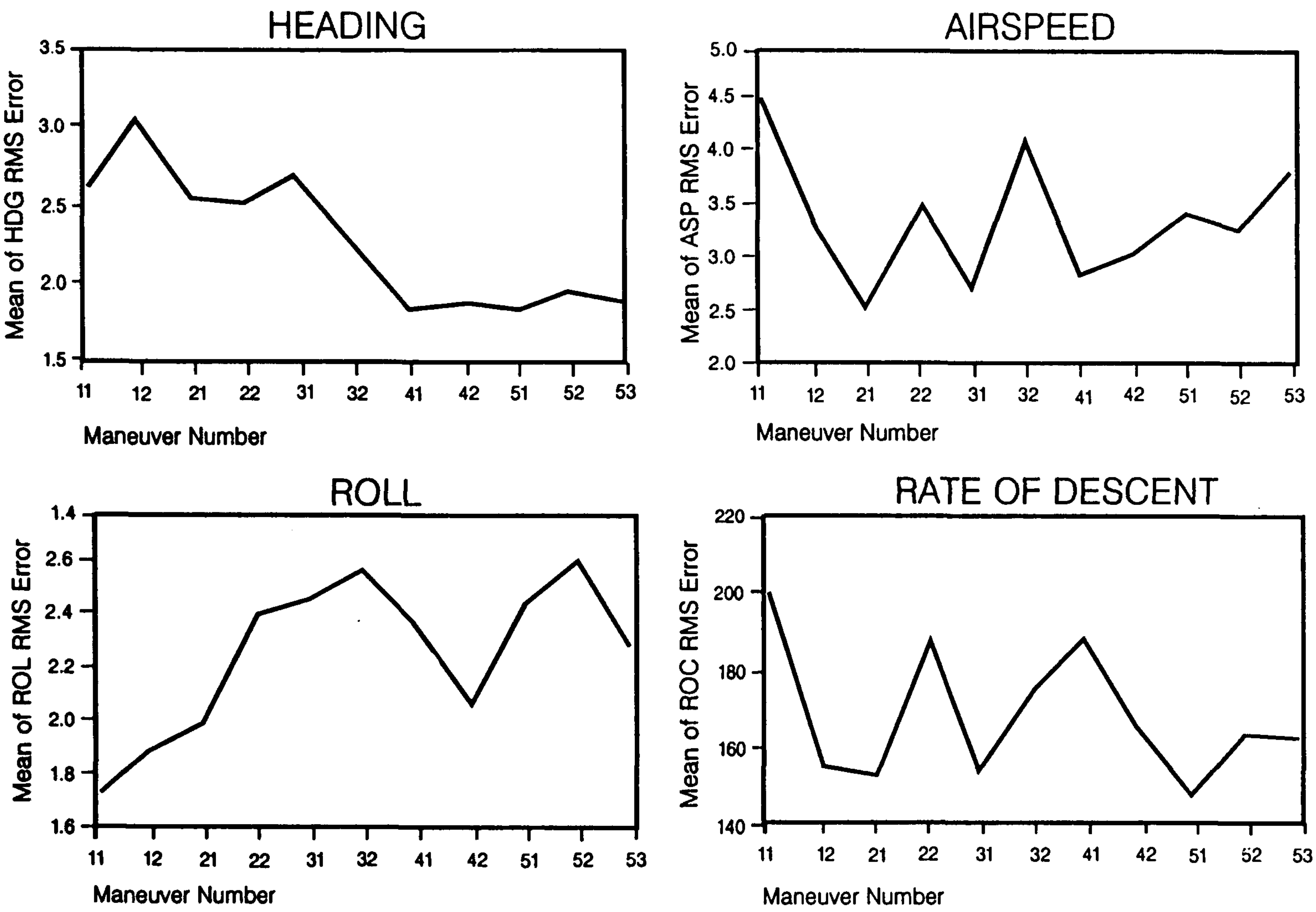

Figure 21. Mean RMS error for descent against maneuver number, training days.

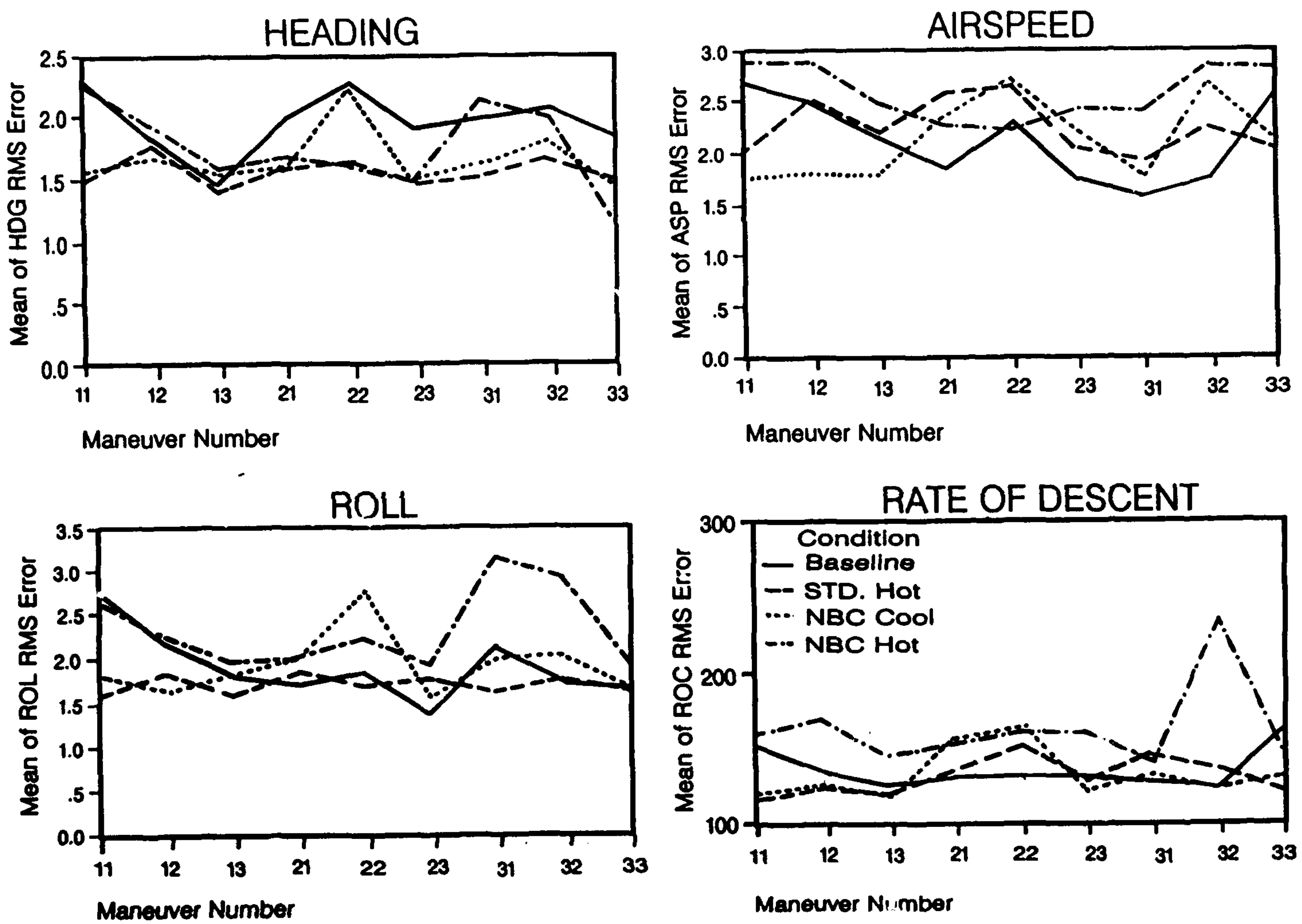

Figure 22. RMS error for descent against maneuver number, test days.

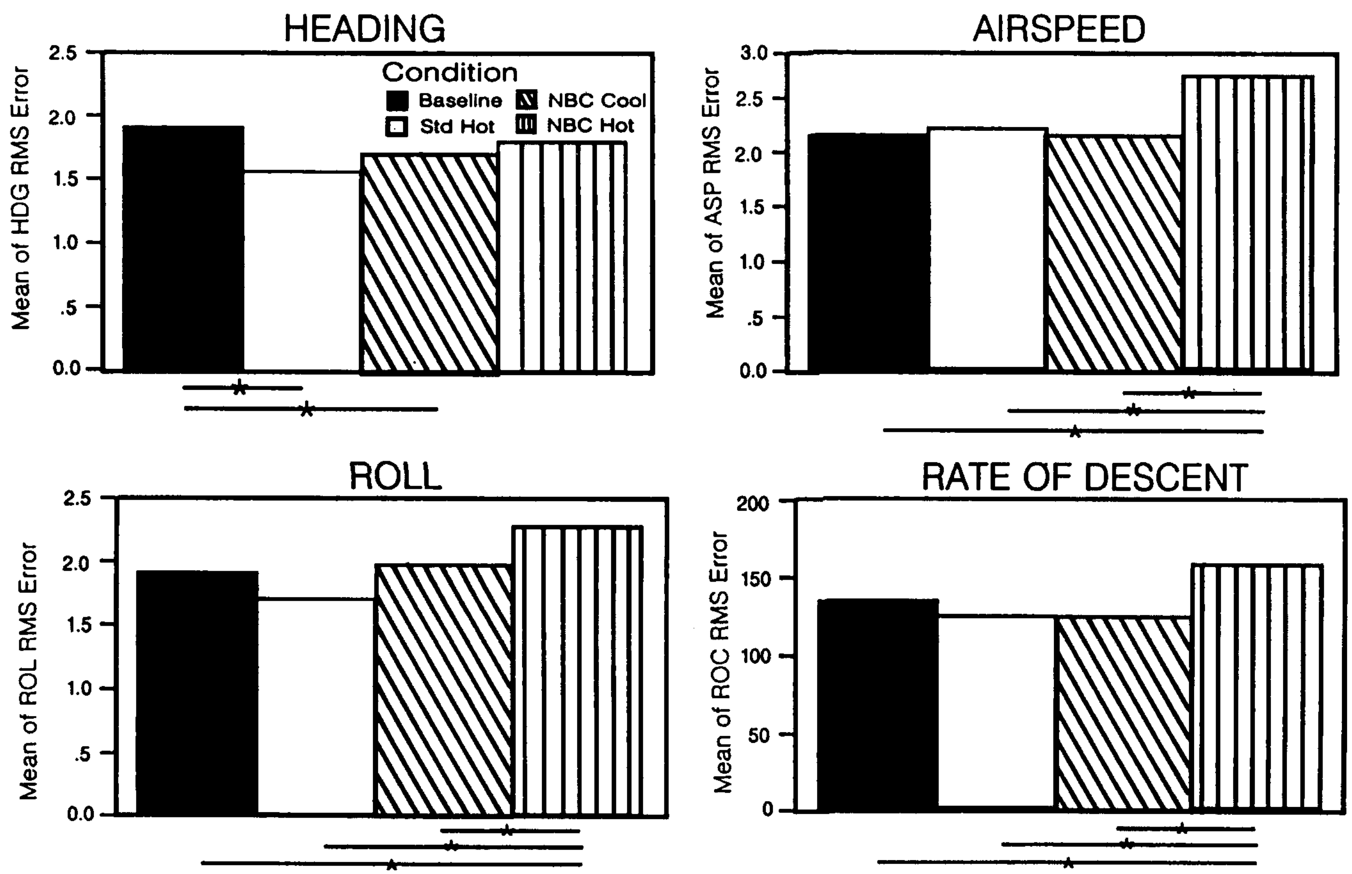

Figure 23. Mean RMS error for descent, test days.

Table 20.
Summary statistics for descent RMS error.

Condition	N	Mean	STD	CV
		Heading		
Baseline	140	1.9569286	1.5208020	77.7137201
Std hot	143	1.5497203	0.7389867	47.6851662
NBC cool	142	1.6597887	0.9730281	58.6236104
NBC hot	110	1.7454545	1.1872817	68.0213481
		Airspeed		
Baseline	140	2.1219286	1.3881471	65.4191247
Std hot	143	2.2462238	1.2977129	57.7730926
NBC cool	142	2.1295070	1.2566523	59.0114166
NBC hot	110	2.5750000	1.5610722	60.6241621
		Roll		
Baseline	140	1.8997857	1.0670854	56.1687225
Std hot	143	1.7045455	0.7940720	46.5855566
NBC cool	142	1.9233099	1.0861714	56.4740744
NBC hot	110	2.2911818	1.5304402	66.7969775
		Rate of descent		
Baseline	140	135.8654286	49.3383686	36.3141449
Std hot	143	132.4262238	45.6700873	34.4871929
NBC cool	142	133.1785915	51.2003713	38.4448963
NBC hot	110	162.4937273	68.7494790	42.3090049
		Slip		
Baseline	140	0.0852143	0.0934585	109.6746537
Std hot	143	0.0777622	0.0715170	91.9687516
NBC cool	142	0.0811972	0.0853818	105.1536059
NBC hot	110	0.0877273	0.0751715	85.6876915

Table 21.
Maximum descent errors.

	Baseline		Std hot		NBC cool		NBC hot	
	Max error	Mean max	Max error	Mean max	Max error	Mean max	Max error	Mean max
Heading	17	3.79	12	3.26	34	3.73	43	3.91
Desc rate	947	375.31	727	336.61	868	359.86	863	401.07
Airspeed	15	4.09	12	4.04	12	4.12	20	4.86
Roll	20	5.99	16	5.24	25	6.06	23	6.95
Slip	2	0.19	2	0.17	2	0.18	2	0.19

Condition (spanning all columns)

Climb

Climb is scored for five parameters: heading, airspeed, roll, rate of climb, and slip. The training data are shown in Figure 24, where RMS error is plotted against maneuver number. There is evidence of initial improvement in performance with practice for airspeed for the first three maneuvers. Performance at the other maneuvers showed an initial deterioration, which soon improved considerably. There is no consistent evidence of a reduction in performance when NBC IPE was donned for the first time at maneuver 32.

Figure 25 plots RMS error against maneuver number for the four test conditions. Climb was flown only before the AFCS was failed. Collapsing across condition, there was no increase in RMS error with flight number for all five parameters. Considering the NBC hot data separately, there was also no change with flight number.

Figure 26 demonstrates the mean of the RMS error for all maneuvers in each condition. For heading, NBC cool had a significantly higher error value than baseline and standard hot. There were no significant differences for any of the other conditions.

The actual values for each condition are shown in Table 22. There was a significant difference between the RMS error scores for subjects for four parameters: heading, airspeed, rate of climb, and slip. Roll showed no significant difference between subjects, the only occasion on which this occurred. Table 23 summarizes the maximum error rates for climb.

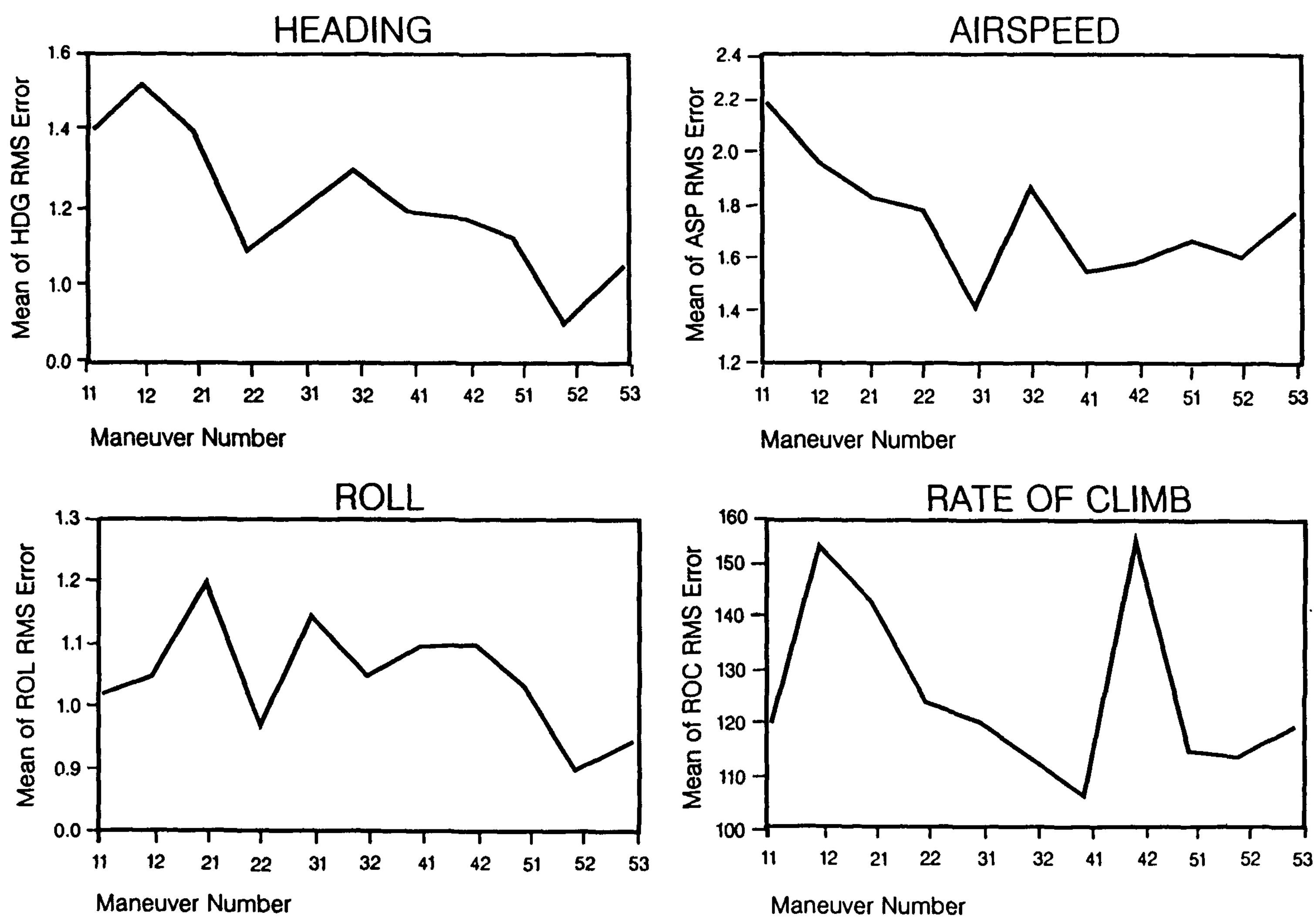

Figure 24. Mean RMS error for climb against maneuver number, training days.

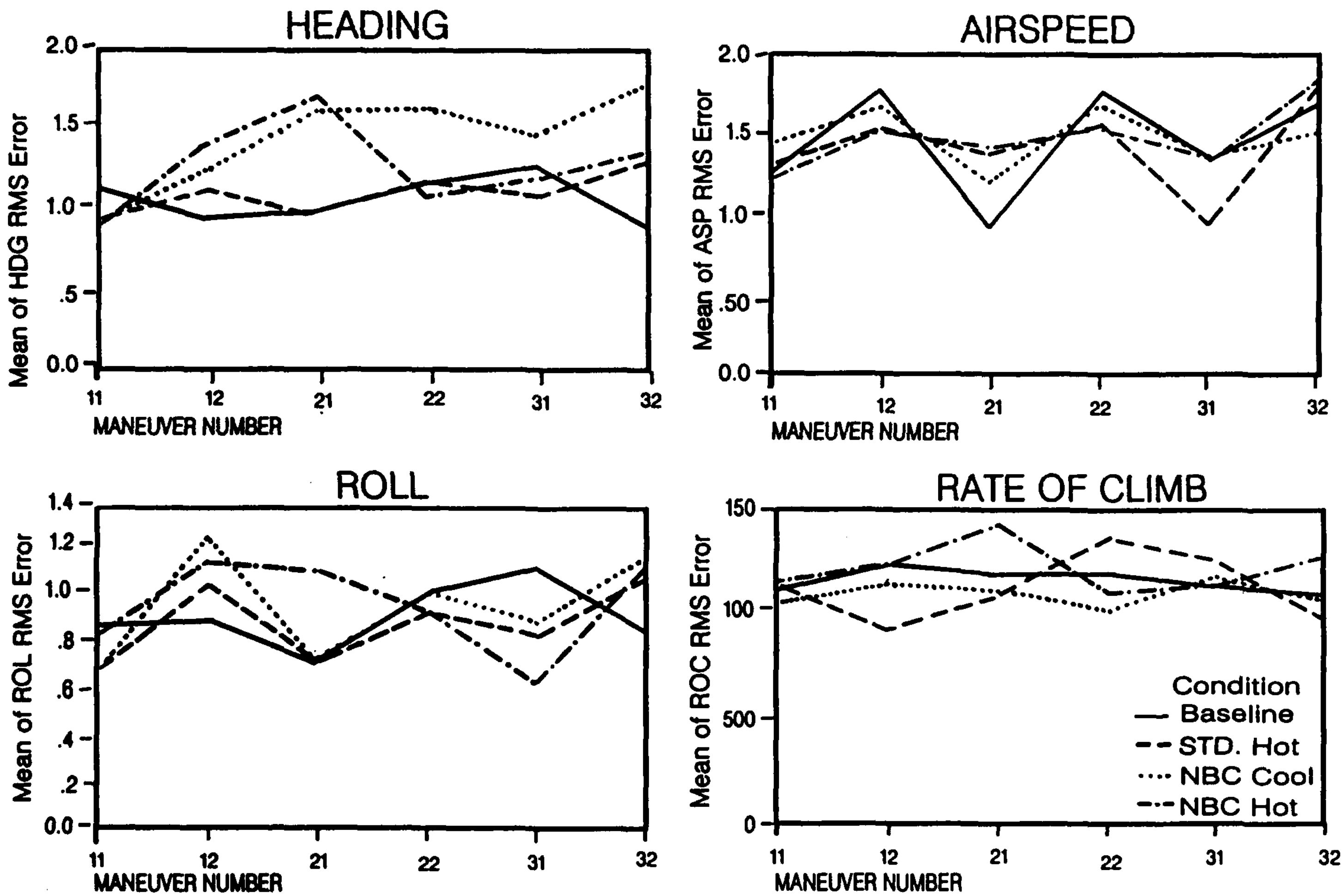

Figure 25. RMS error for climb against maneuver number, test days.

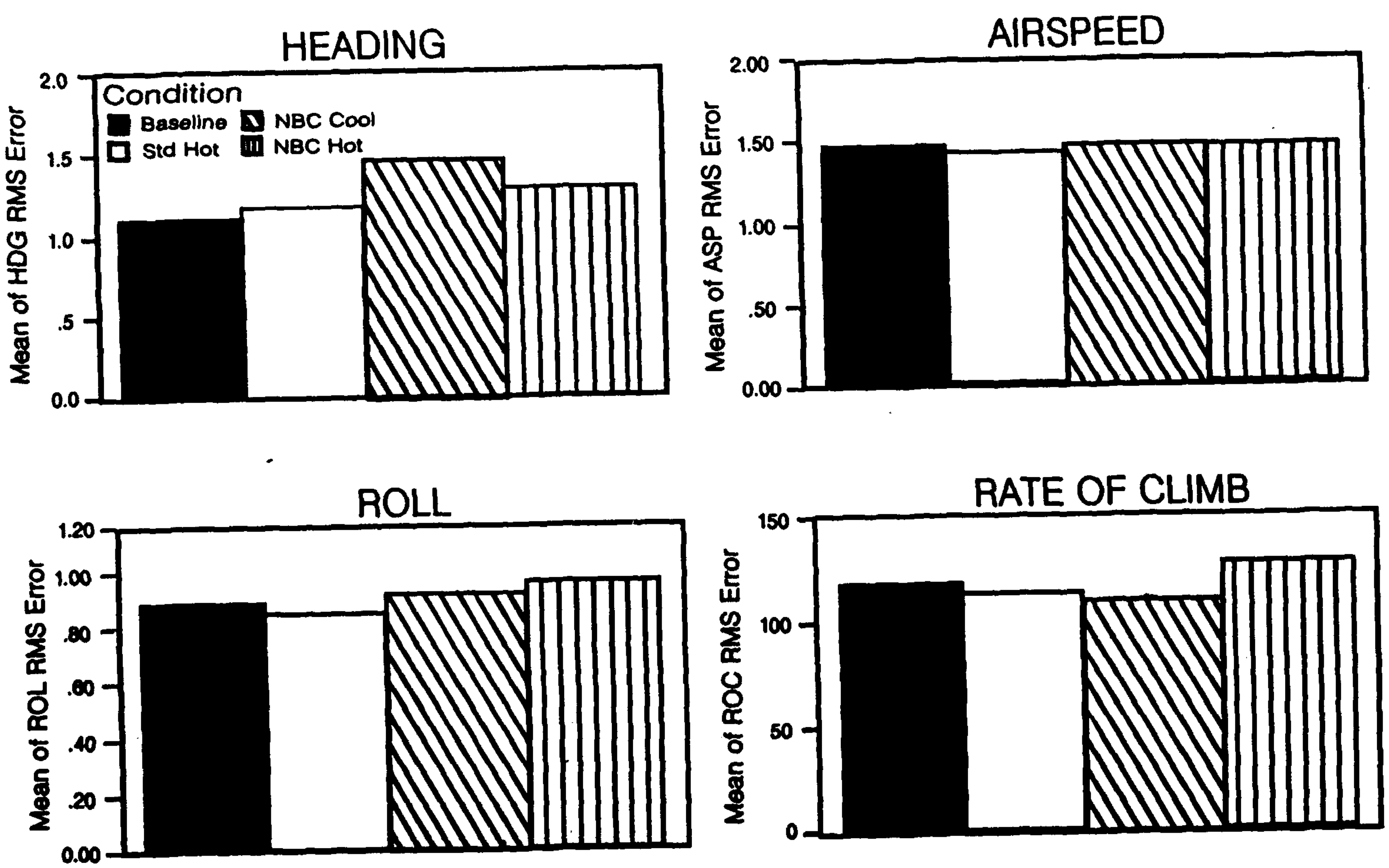

Figure 26. Mean RMS error for climb, test days.

Table 22.
Summary statistics for climb RMS error.

Condition	N	Mean	STD	CV
		Heading		
Condition	N	Mean	STD	CV
Baseline	96	1.0525000	0.4888074	46.4425042
Std hot	97	1.1002062	0.4495785	40.8631095
NBC cool	95	1.4256842	1.3202213	92.6026481
NBC hot	74	1.2625676	1.5071738	119.3737118
		Airspeed		
Condition	N	Mean	STD	CV
Baseline	96	1.4605208	1.1359433	77.7765874
Std hot	97	1.4224742	0.8820490	62.0080848
NBC cool	95	1.4804211	0.8648772	58.4210288
NBC hot	74	1.4645946	0.7808973	53.3183213
		Roll		
Condition	N	Mean	STD	CV
Baseline	96	0.9220833	0.5361008	58.1401648
Std hot	97	0.8945361	0.4286680	47.9207104
NBC cool	95	0.9598947	0.5712388	59.5105717
NBC hot	74	0.9905405	1.0472546	105.7255654
		Rate of climb		
Condition	N	Mean	STD	CV
Baseline	96	115.9937500	65.5963426	56.5516181
Std hot	97	112.4922680	68.8194511	61.1770500
NBC cool	95	109.3857895	46.8344758	42.8158685
NBC hot	74	122.7229730	68.1576061	55.5377730
		Slip		
Condition	N	Mean	STD	CV
Baseline	96	0.0735417	0.0804851	109.4414920
Std hot	97	0.0768041	0.0877680	114.2751128
NBC cool	95	0.0765263	0.0880857	115.1050448
NBC hot	74	0.0828378	0.0814176	98.2854987

Table 23.
Maximum climb errors.

	Condition							
	Baseline		Std hot		NBC cool		NBC hot	
	Max error	Mean max	Max error	Mean max	Max error	Mean max	Max error	Mean max
Heading	9	2.22	7	2.15	10	2.58	48	2.88
Climb rate	1081	374.37	925	367.85	1136	366.42	752	395.59
Airspeed	10	2.71	8	2.63	10	2.88	8	2.86
Roll	13	2.76	21	2.73	12	2.83	21	2.70
Slip	1	0.14	1	0.15	1	0.15	1	0.15

Straight and level

Straight and level is scored for five parameters: heading, altitude, airspeed, roll, and slip. The training data are shown in Figure 27, where RMS error is plotted against maneuver number. There is evidence of a steady improvement in performance throughout the week for heading and altitude. There is no consistent evidence of a reduction in performance when NBC IPE was donned for the first time at maneuver 32.

Figure 28 plots RMS error against maneuver number for the four test conditions. The data are plotted before separating into AFCS in and AFCS out, which is responsible for the saw-tooth appearance. Collapsing across conditions, there was no increase in RMS error with flight number, for all five parameters. NBC cool clearly had a greater error rate for heading than the other conditions, which was worse for flights two and three than flight one. The NBC hot data showed a significantly greater error in altitude for flight three over flights one and two.

Figure 29 demonstrates the mean of the RMS error for all maneuvers in each condition. For heading, AFCS in, the NBC cool condition had a significantly higher error value than any of the others. There were no significant differences with the AFCS out. For altitude and airspeed, AFCS out, hot NBC error was significantly higher than the other conditions. There were no significant differences with the AFCS in. Roll with the AFCS out produced a significantly greater error for NBC hot compared with NBC cool, and no differences with the AFCS in. For slip, there were no significant differences for any condition.

Collapsing across condition, the difference in RMS error value between AFCS in and AFCS out was significant for all parameters except slip, with AFCS out always producing the higher error. The actual values for each condition are shown in Table 24. There was a significant difference between the RMS error scores for subjects for all five parameters.

Table 25 shows the maximum errors for straight and level.

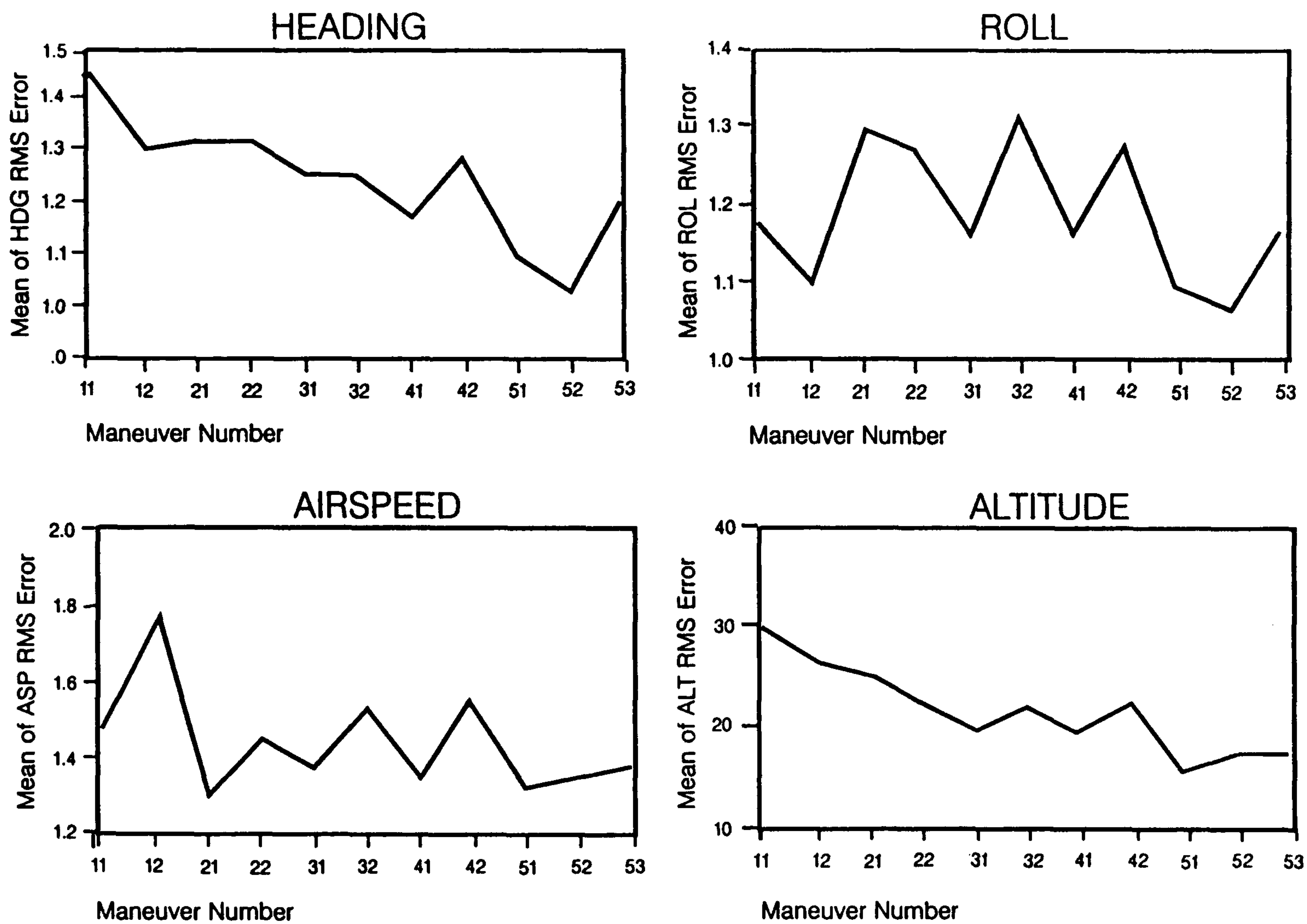

Figure 27. Mean RMS error for straight and level against maneuver number, training days.

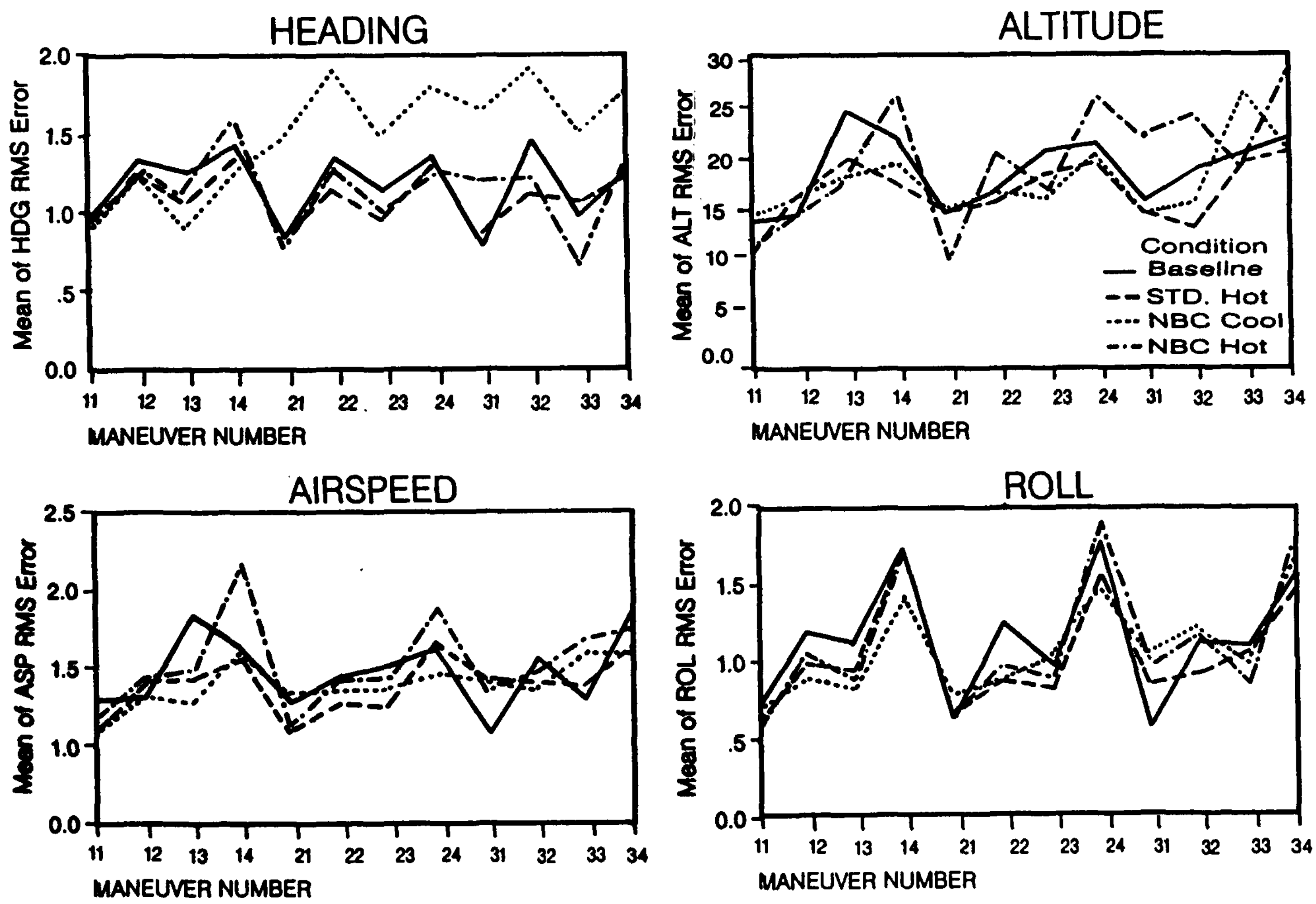

Figure 28. RMS error for straight and level against maneuver number, test days.

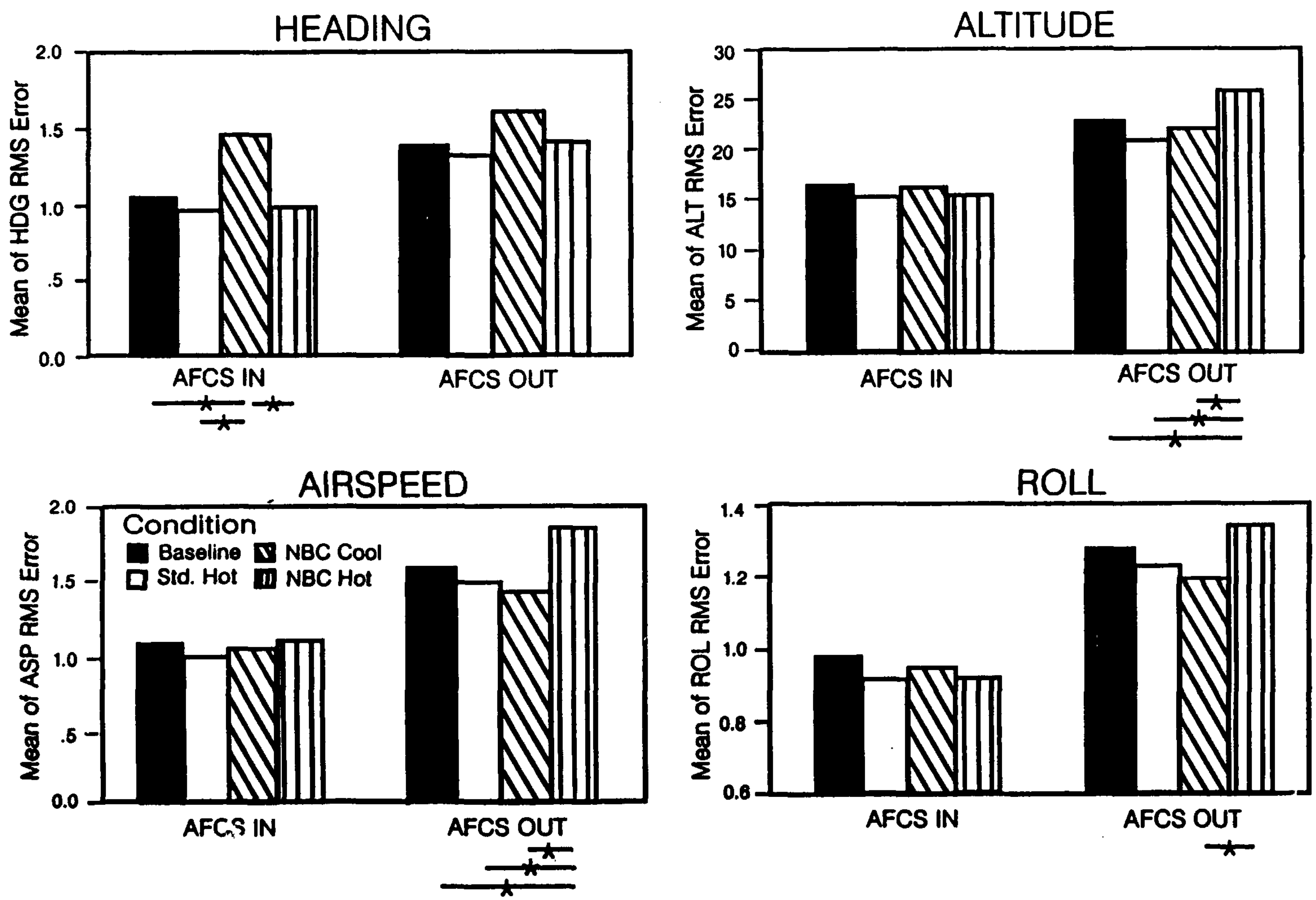

Figure 29. Mean RMS error for straight and level, test days.

Table 24.
Summary statistics for straight and level RMS error.

Condition	N	Mean	STD	CV
Heading - AFCS in				
Baseline	144	1.1056250	0.6289993	56.8908389
Std hot	146	1.0100000	0.4993099	49.4366206
NBC cool	142	1.4213380	1.3057430	91.8671706
NBC hot	111	1.0318919	0.5116542	49.5840900
Heading - AFCS out				
Baseline	48	1.3625000	0.5185434	38.0582295
Std hot	48	1.2937500	0.5521356	42.6771480
NBC cool	46	1.6060870	1.4387178	89.5790700
NBC hot	36	1.4016667	0.5967603	42.5750512
Altitude - AFCS in				
Baseline	144	17.4465278	11.9387215	[illegible].4303586
Std hot	146	15.7680822	10.1137788	64.1408301
NBC cool	142	16.6869718	11.1980545	67.1065703
NBC hot	111	16.3723423	11.3909146	69.5741293
Altitude - AFCS out				
Baseline	48	21.3316667	11.5134122	53.9733365
Std hot	48	18.8779167	10.5172760	55.7120584
NBC cool	46	19.5904348	10.2366075	52.2530899
NBC hot	36	26.5102778	11.9402018	45.0398971
Airspeed - AFCS in				
Baseline	144	1.1180556	0.6288343	56.2435633
Std hot	146	1.0129452	0.6179021	61.0005442
NBC cool	142	1.0388028	0.6564600	63.1938958
NBC hot	111	1.0997297	0.5950805	54.1115251
Airspeed - AFCS out				
Baseline	48	1.5070833	0.6294339	41.7650374
Std hot	48	1.4050000	0.5568108	39.6306639
NBC cool	46	1.3167391	0.5371780	40.7960865
NBC hot	36	1.8475000	0.8430773	45.6334112

Table 24 (Continued).
Summary statistics for straight and level RMS errors.

Condition	N	Mean	STD	CV
		Roll - AFCS in		
Baseline	144	0.9670139	0.5768422	59.6519080
Std hot	146	0.8505479	0.4871915	57.2797224
NBC cool	142	0.9221831	0.5622146	60.9656167
NBC hot	111	0.8771171	0.4707448	53.6695534
		Roll - AFCS out		
Condition	N	Mean	STD	CV
Baseline	48	1.6920833	0.7210069	42.6105997
Std hot	48	1.5729167	0.7413357	47.1312731
NBC cool	46	1.5182609	0.5562825	36.6394558
NBC hot	36	1.8138889	0.6307106	34.7711822
		Slip - AFCS in		
Condition	N	Mean	STD	CV
Baseline	144	0.0611806	0.0636478	104.0327476
Std hot	146	0.0646575	0.0765476	118.3893170
NBC cool	142	0.0649296	0.0757070	116.5986887
NBC hot	111	0.0683784	0.0867446	126.8596372
		Slip - AFCS out		
Condition	N	Mean	STD	CV
Baseline	48	0.0562500	0.0586234	104.2193641
Std hot	48	0.0481250	0.0360647	74.9397028
NBC cool	46	0.0543478	0.0744954	137.0715434
NBC hot	36	0.0588889	0.0588838	99.9913539

Table 25.
Maximum straight and level errors.

	Condition							
	Baseline		Std hot		NBC cool		NBC hot	
	Max error	Mean max	Max error	Mean max	Max error	Mean max	Max error	Mean max
Heading	8	2.34	9	2.16	10	2.58	7	2.29
Altitude	109	34.14	97	30.26	106	31.62	132	34.83
Airspeed	9	2.50	6	2.15	7	2.24	8	2.54
Roll	17	3.53	16	3.15	18	3.32	12	3.33
Slip	1	0.12	1	0.14	2	0.12	1	0.12

Simulator instructor/operator comments

There was no formal subjective assessment of subjects in this study. The simulator instructor/operator did, however, make a number of observations, noting in particular the occasions on which the simulator 'crashed' into the terrain or hit trees. There were seven crashes. One was in the baseline condition, the remainder in NBC, two hot and four cool.

Survival time

The simplest measure of the ability to operate in NBC protective clothing is 'survival time,' that is the length of time that the equipment can be endured before the subject removes himself from the experiment or the physiological criteria are met. Only two subjects were withdrawn for reaching the physiological monitoring criteria, both with a rectal temperature of 39.5°C. All subjects survived the full 6 hours in the three less stressful conditions. In the hot NBC condition, the mean survival time was 298 minutes (STD 88). Nine subjects lasted the full 6 hours and the minimum survival time was 1 hour. The actual survival times are shown in Table 26.

Table 26.
Survival time.

Subject number	Survival time (min)
03	360
04	276
05	180
06	60
07	360
09	180
10	360
11	320
12	240
13	360
14	360
15	360
16	360
17	360
18	270
19	360

Physiology

Rectal temperature

Figure 30 plots the mean rectal temperature recorded at 1-minute intervals on the treadmill and walking to the simulator. There was a small increase for all conditions between the start and end of recording, which is most marked for the NBC hot condition. The significance of differences between the various curves was determined by plotting the 99 percent confidence intervals for selected curves. The lower confidence interval for the curve with higher temperatures is plotted against the upper confidence interval for the one it is being compared with. Figure 31 demonstrates this for the treadmill rectal temperature. The lower confidence interval for NBC hot is plotted against the upper confidence interval for standard hot and NBC cool. In both cases, there is no overlap, indicating that the NBC hot condition produced significantly higher rectal temperatures on the treadmill.

Figure 32 shows the mean rectal temperature for the period during which subjects were in the simulator, plotted at 5-minute intervals. There is a variable gap between the end of the data in Figure 30 and the start of those in Figure 32, as the subjects underwent the process of strapping into the simulator and connecting to the data-recording apparatus, during which time rectal temperature continued to rise before recording resumed.

Figure 33 shows confidence intervals for the simulator rectal temperatures. The lower confidence interval for NBC hot is plotted against the upper confidence intervals for standard hot and NBC cool, and both are clearly well separated. The similarity in the slopes for the NBC hot and standard hot curves is noteworthy, suggesting little difference between the rate of rise in the two conditions. This should not be considered in isolation from the raw data in Figure 32, however, because the relatively gentle slope produced by the regression equation includes the plateau beyond 200 minutes, when the subjects with the higher rectal temperatures had already left the data set. The third graph plots the lower confidence interval for standard hot against the upper confidence interval for the baseline data. The standard hot data became significantly higher after about 60 minutes.

Baseline and NBC cool conditions produced a fall in rectal temperature in the simulator from the elevation caused by the period of initial exercise (37.4 to 36.9°C and 37.4 to 36.6°C respectively). The temperatures are remarkably consistent across conditions. The dip in the NBC cool curve at the end was caused by the inconsistency in the total length of time in the simulator between individuals. This was due to a variety of factors such as short periods of simulator unserviceability and differences between the practices of different simulator operators. The number of subjects included in the data fell from 16 at 330 minutes to 3 at 350 minutes. The three remaining clearly had lower rectal temperatures.

The standard hot condition showed a small rise in mean rectal temperature in the simulator from 37.1 to 37.4°C. The NBC hot condition produced a rise of 1°C (37.6 to 38.6°C). Because of the greater rise during the exercise phase than for the other conditions, the final temperature was 1.8° higher than the final baseline temperature.

There are two features of the simulator physiology graphs which are due to artifact. The first is that data were lost during the 10-minute breaks between flights, when the flight data recording program was not running. As these gaps did not correspond exactly between different pairs of subjects due to delays in flights caused by simulator problems or variability between operators, there are periods of several minutes when the number of subjects contributing to the mean fell, causing the relatively ragged appearance of some of the curves.

The second artifact is due to the loss of subjects from the data pool on the NBC hot day, as they dropped out. This produced similar effects on the NBC hot curve, but in a more pronounced way, as those individuals remained out of the data pool for the rest of that day. It also explains why the curve starts to flatten with time, particularly beyond 200 minutes, as those subjects with higher rectal temperatures tended to be the ones who withdrew. This is illustrated in Figure 34, which plots rectal temperature separately for the four conditions, with the data sorted into 'survivors,' those who completed all flights on the NBC hot day, and 'nonsurvivors,' who did not. For the other three conditions, the data for the two groups are remarkably similar. However, on the hot NBC day, the rectal temperature for nonsurvivors was clearly climbing at a much faster rate than that for the survivors.

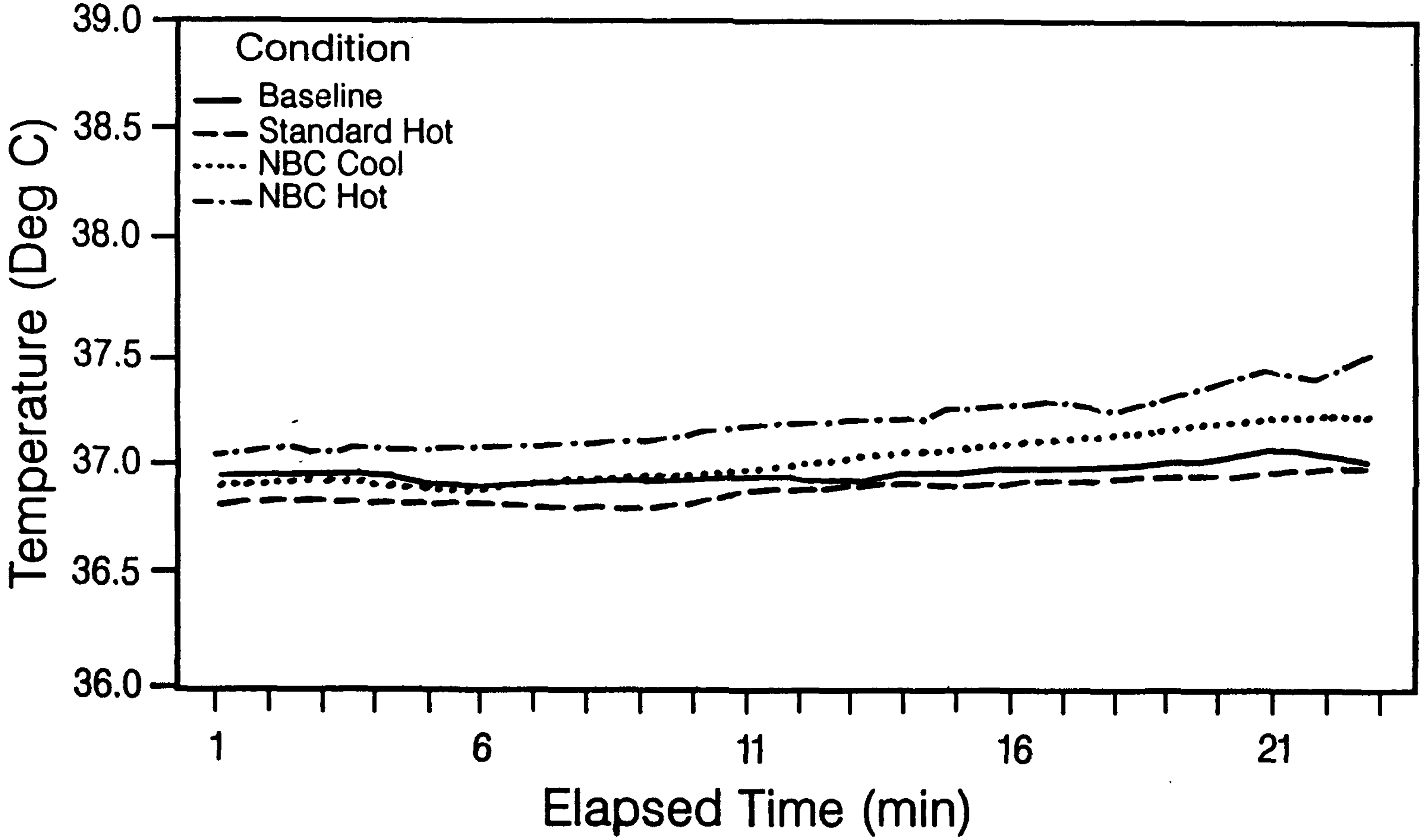

Figure 30. Rectal temperature during treadmill.

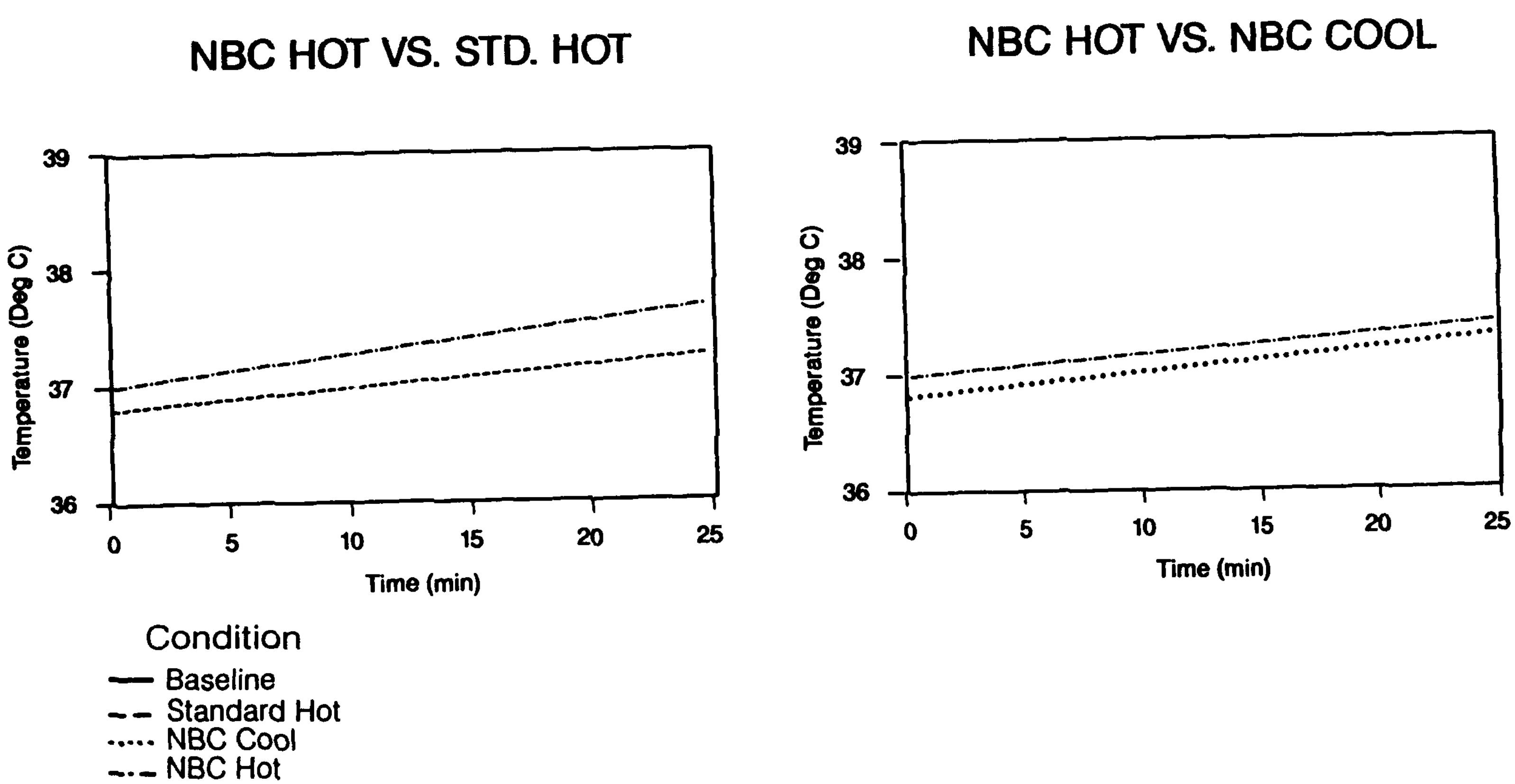

Figure 31. Rectal temperature confidence intervals during treadmill.

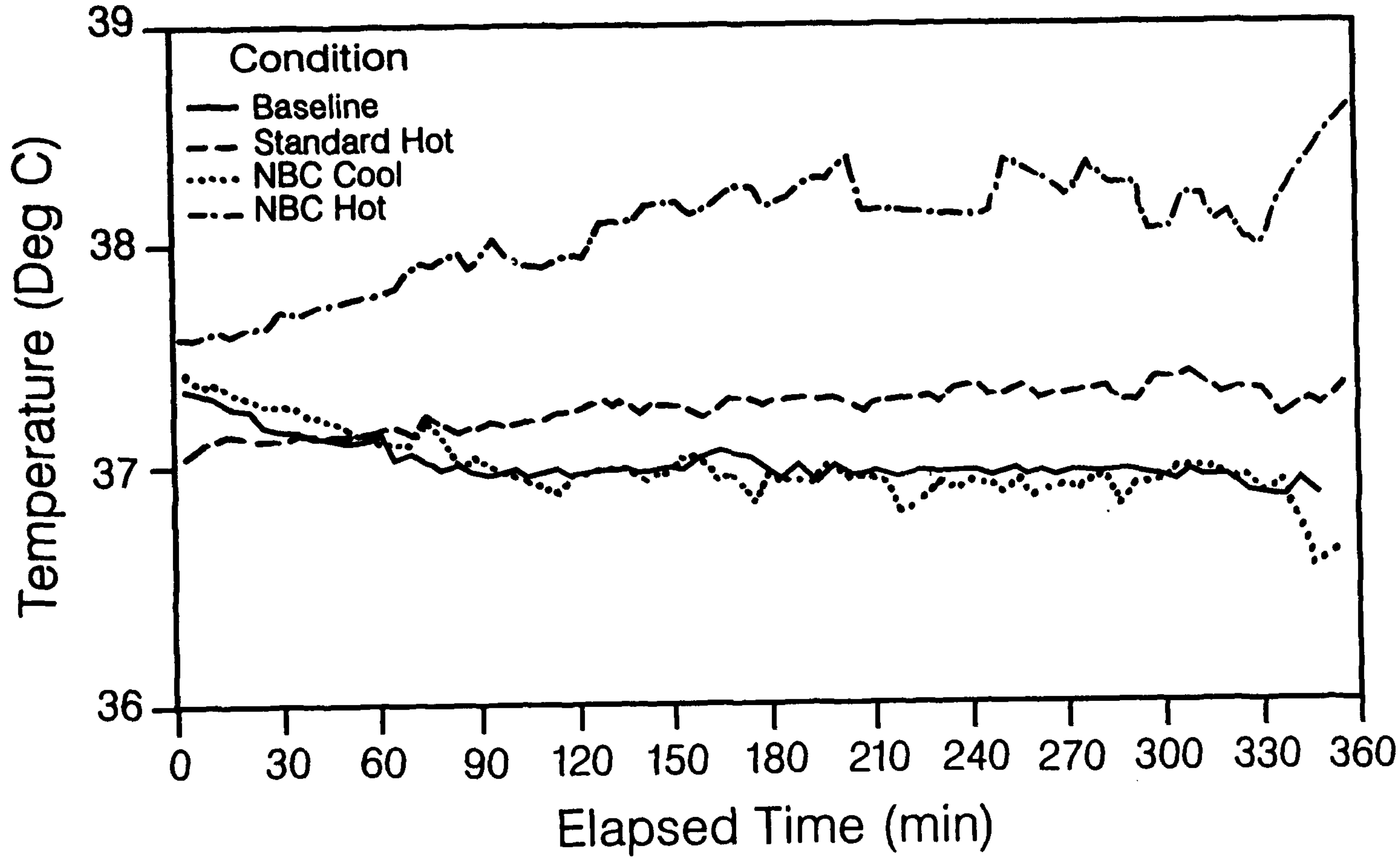

Figure 32. Rectal temperature in simulator.

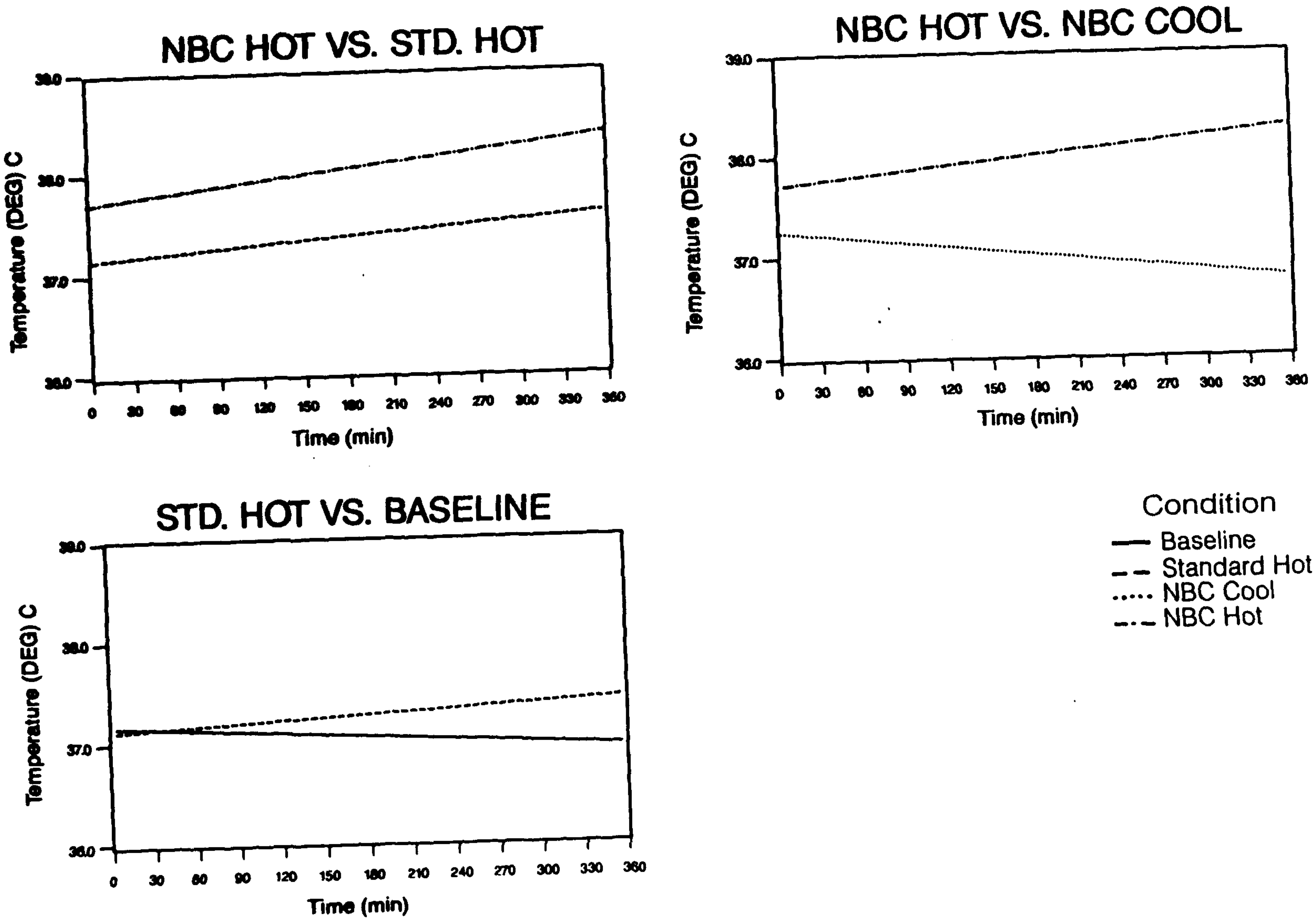

Figure 33. Rectal temperature confidence intervals in simulator.

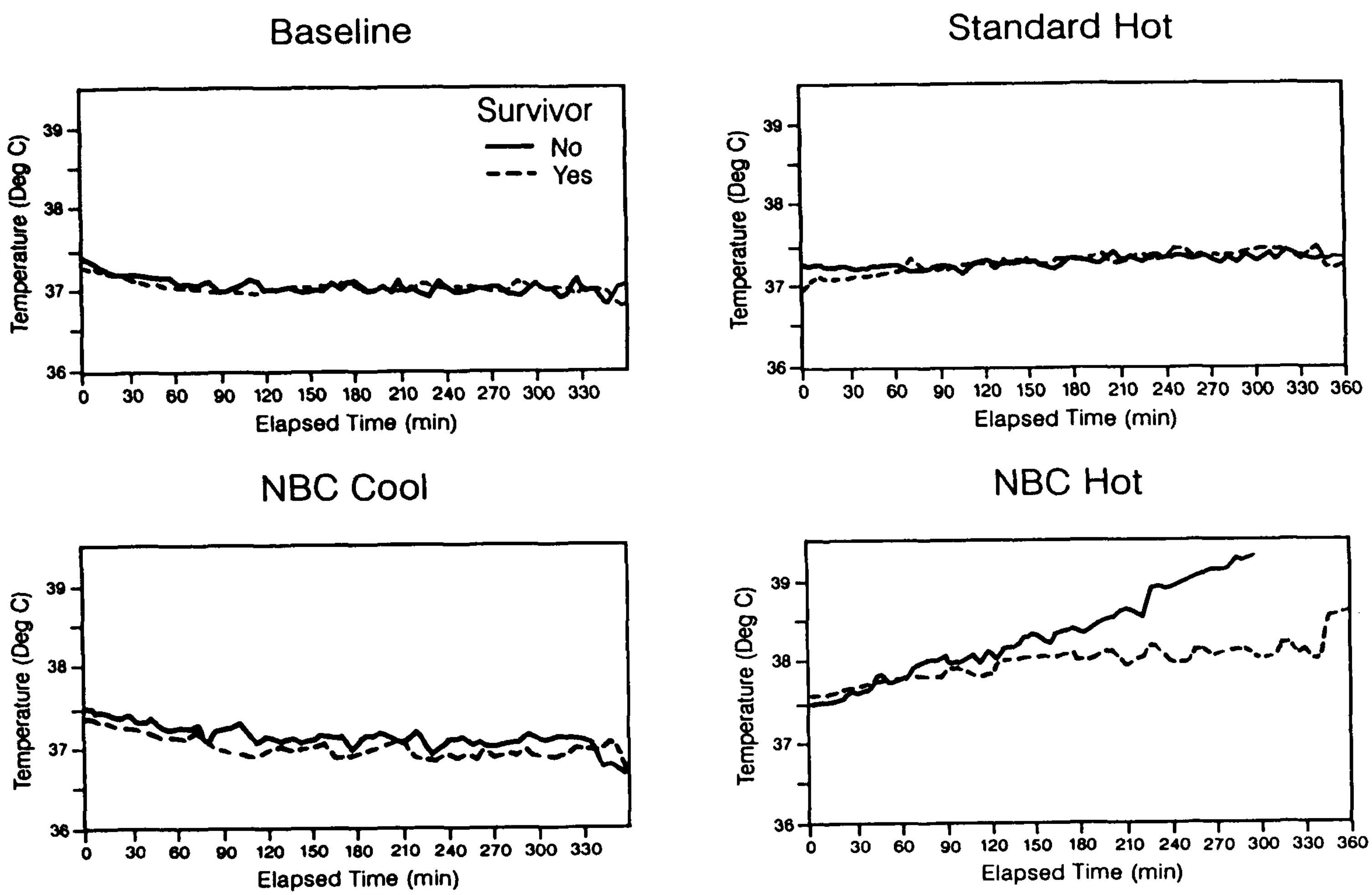

Figure 34. Rectal temperature for survivors and nonsurvivors in simulator.

Mean skin temperature

The graph plotting mean skin temperature against time on the treadmill, at 1-minute intervals, is shown in Figure 35. The initial temperatures for both the NBC conditions, with their higher clothing insulation, were already half a degree higher than in the non-NBC conditions by the time they got to the treadmill. The value for the hot standard condition rapidly climbed in the first minute of exercise at the higher temperature, but it still did not reach that of the NBC cool condition. The NBC hot condition produced a marked rise of 1.6°C, while the baseline condition caused virtually no rise at all.

Figure 36 contains the confidence intervals for the treadmill mean skin temperature data. The lower confidence interval for the NBC hot condition is plotted against the upper confidence interval for standard hot and NBC cool. NBC hot is significantly greater in both cases. The lower confidence intervals for NBC cool and standard hot, plotted against the upper for baseline, show that both conditions produced significantly higher mean skin temperatures on the treadmill.

In Figure 37, which shows the simulator mean skin temperature data, by the time the subjects had been connected to the recording hardware in the simulator, there was a wide separation in initial temperatures. The standard hot skin temperature then was higher than in the NBC condition, the opposite of the situation at the end of the data logger recording a few minutes earlier. The temperature in the simulator was considerably higher than that achieved during the treadmill simulation (WBGT 8°C higher, see below), enough to raise the skin temperature 1.1°C in the first few minutes.

The skin temperature elevation produced by exercising in the NBC assembly, even in the cool condition, rapidly fell initially, though the added insulation kept it higher than the baseline temperature throughout the flight. The mean skin temperatures in the two hot conditions quickly stabilized and showed no appreciable further rise. The temperatures for NBC hot and standard hot clearly were much higher than for the two cooler conditions, and this is confirmed by the confidence interval plots in Figure 38.

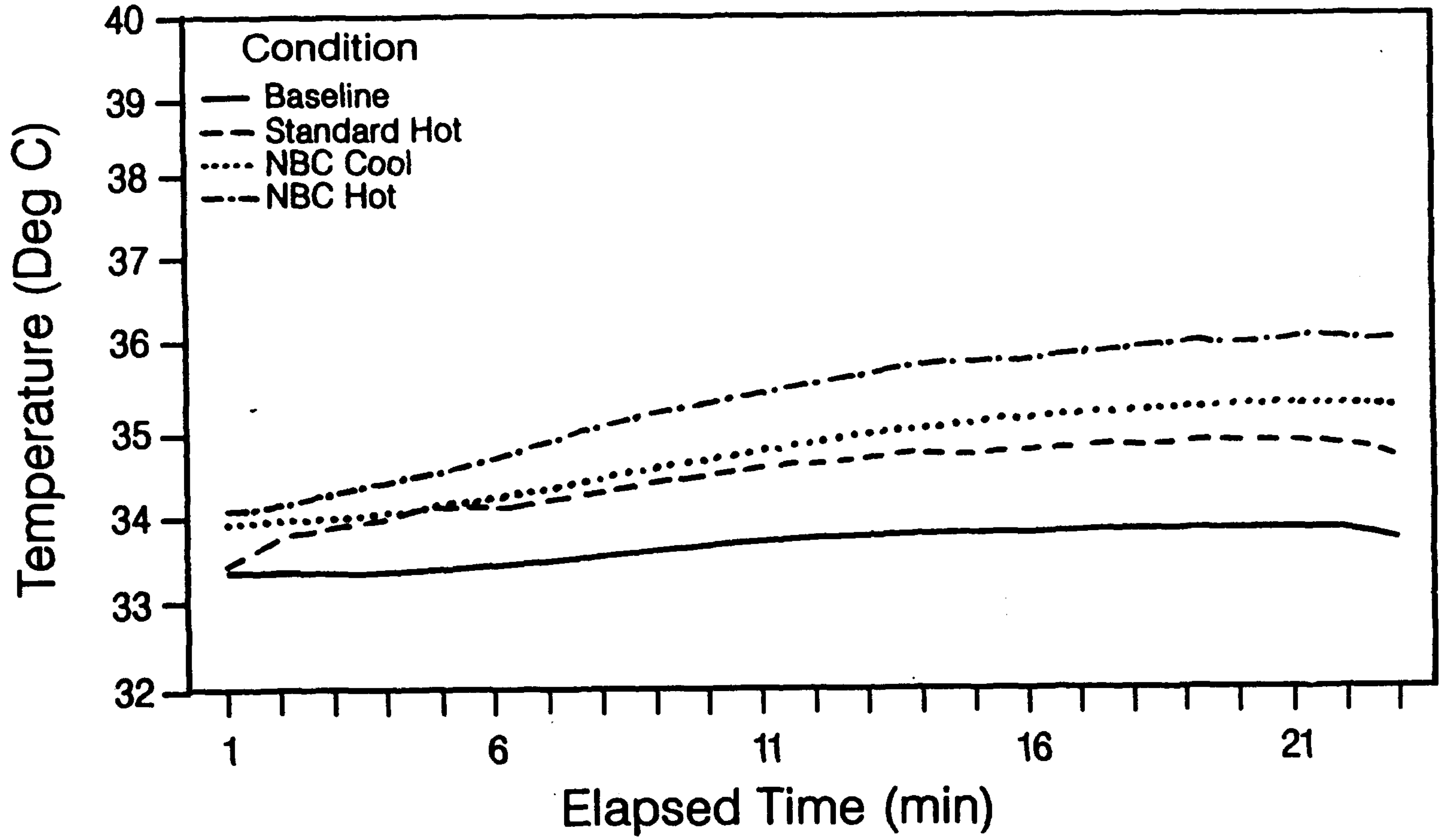

Figure 35. Mean skin temperature during treadmill.

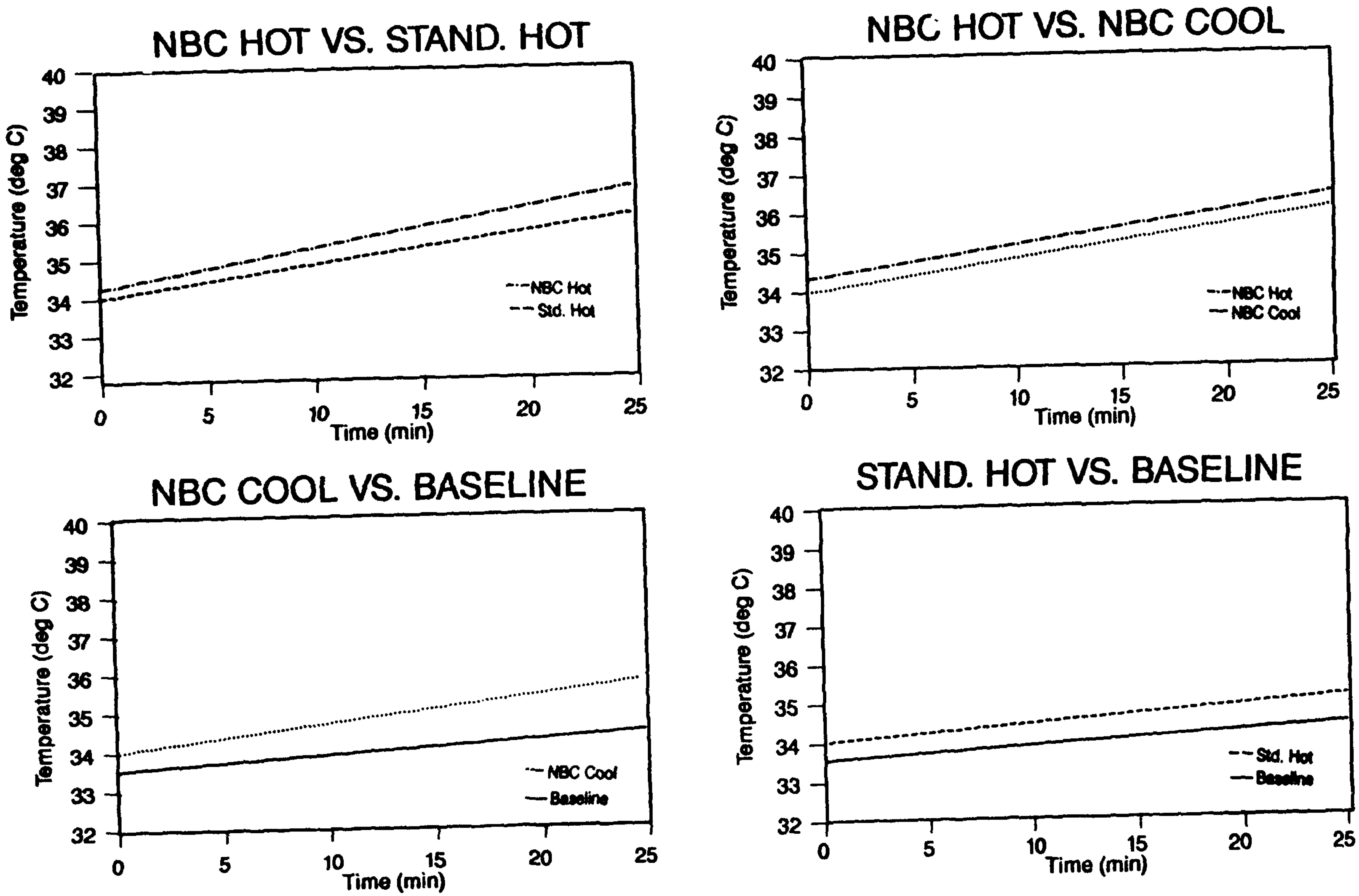

Figure 36. Mean skin temperature confidence intervals during treadmill.

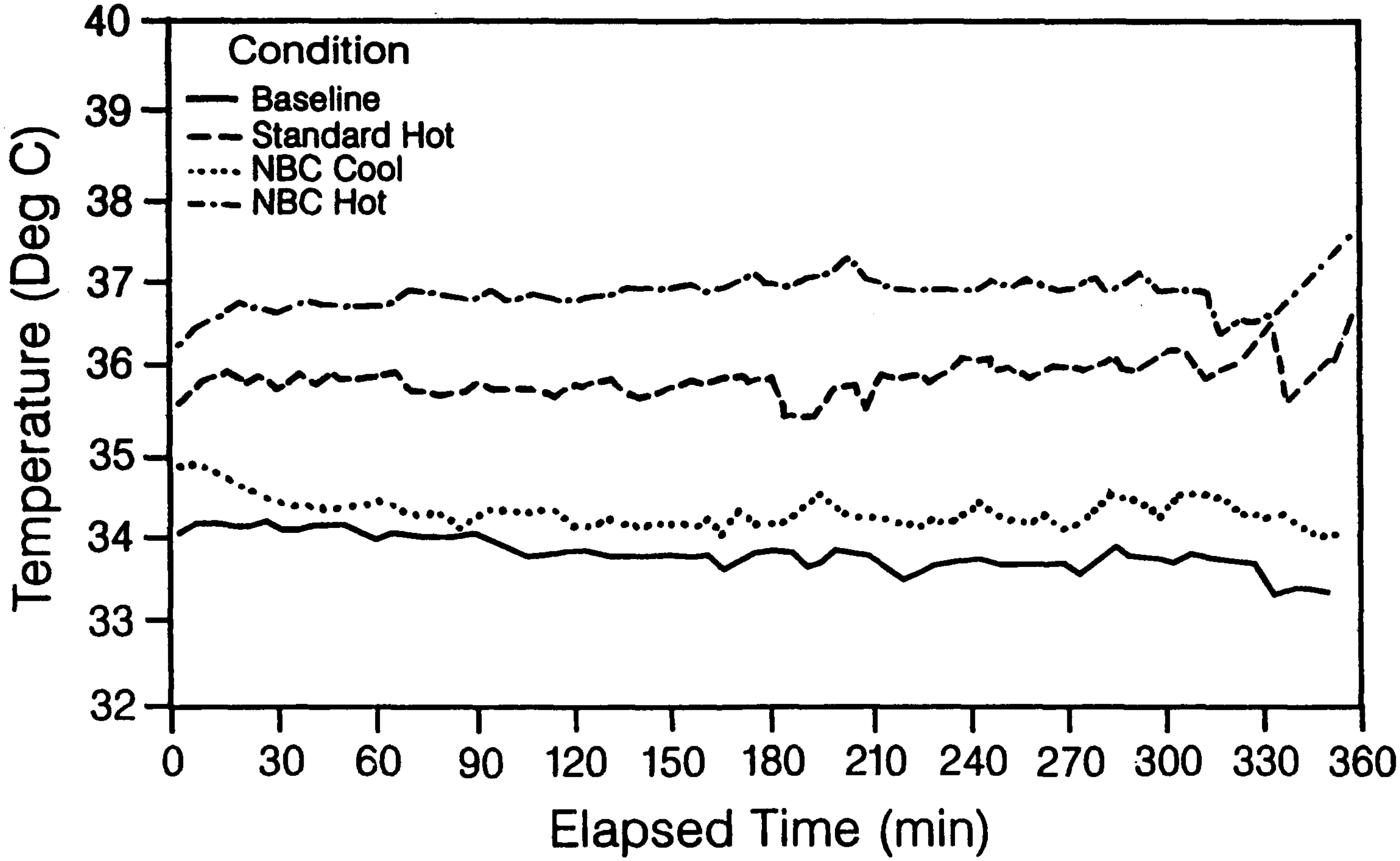

Figure 37. Mean skin temperature in simulator.

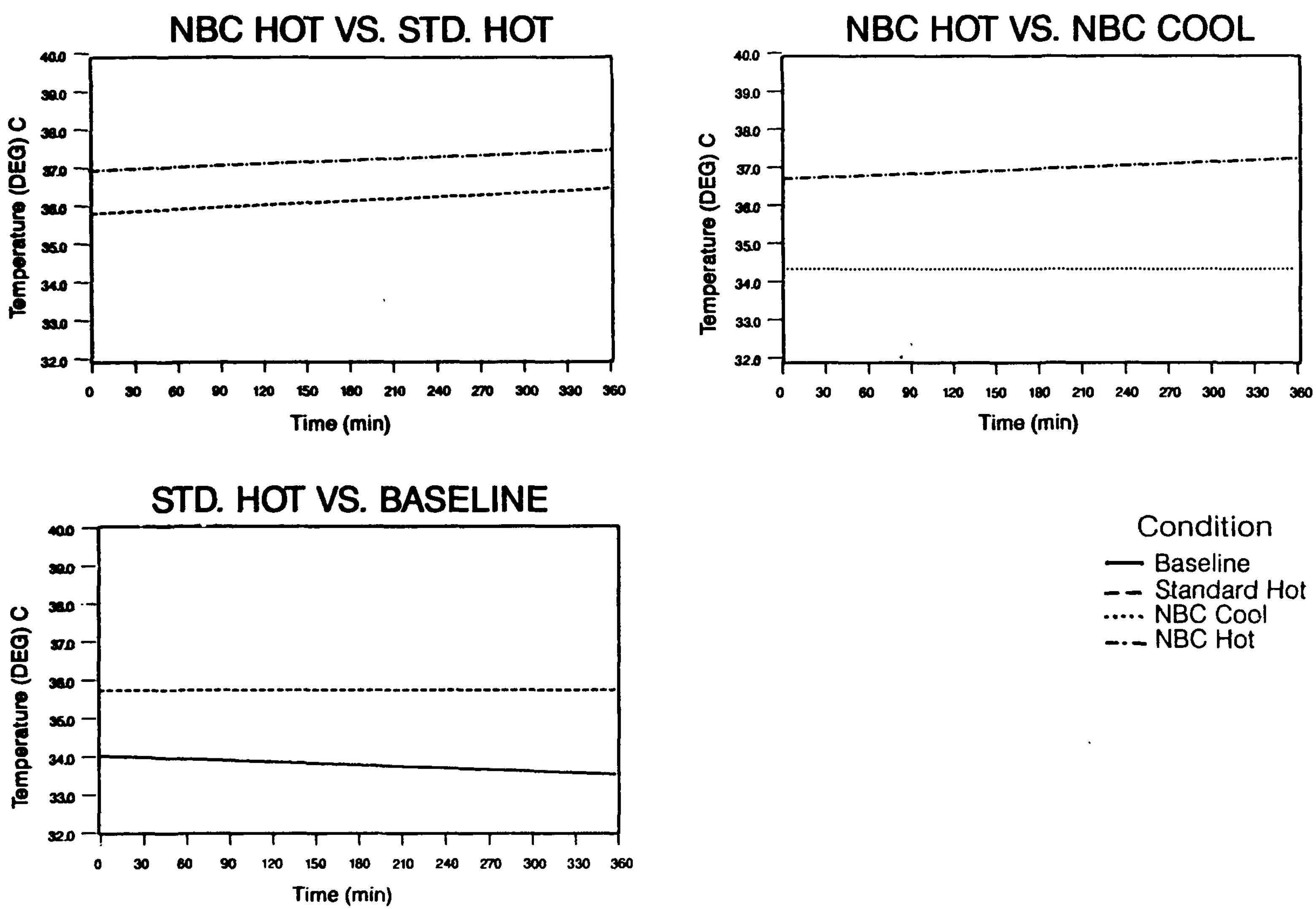

Figure 38. Mean skin temperature confidence intervals in simulator.

Heart rate

Figure 39 plots heart rate against time for the treadmill, at 1-minute intervals. Wearing the NBC assembly in the heat caused the heart rate to be appreciably higher than in the other conditions. All four conditions produced a rise in the second minute of about 10 beats per minute (bpm). There was little difference for the remainder of the period between the baseline and NBC cool values, with the standard hot rate appearing slightly higher.

The rate for the NBC hot condition continued to rise until the exercise period ended at 20 minutes, albeit at a slower rate for the final few minutes For the other three conditions, the rate plateaued after the first few minutes. All rates quickly slowed after the treadmill was stopped, apart from the baseline. The overall heart rate for the NBC hot condition was significantly faster than for the other conditions, as shown by the confidence interval plots in Figure 40.

In Figure 41, heart rate is plotted at 5-minute intervals for the simulator exposure. For the two cool conditions, heart rate slowed initially as they recovered from the exercise period and the exertion of strapping into the seat. The rate for the standard hot condition showed a slight initial slowing, but the heat exposure kept it consistently higher than baseline for the remainder of the flight. In the NBC hot condition, there was no initial slowing, and it continued to climb throughout the time in the simulator. The final value was 29 bpm faster than the initial one, and 64 bpm higher than the final NBC cool rate.

The confidence interval plots in Figure 42 indicate that the rate for NBC hot was significantly faster than standard hot or baseline conditions, and that standard hot also was significantly greater than baseline.

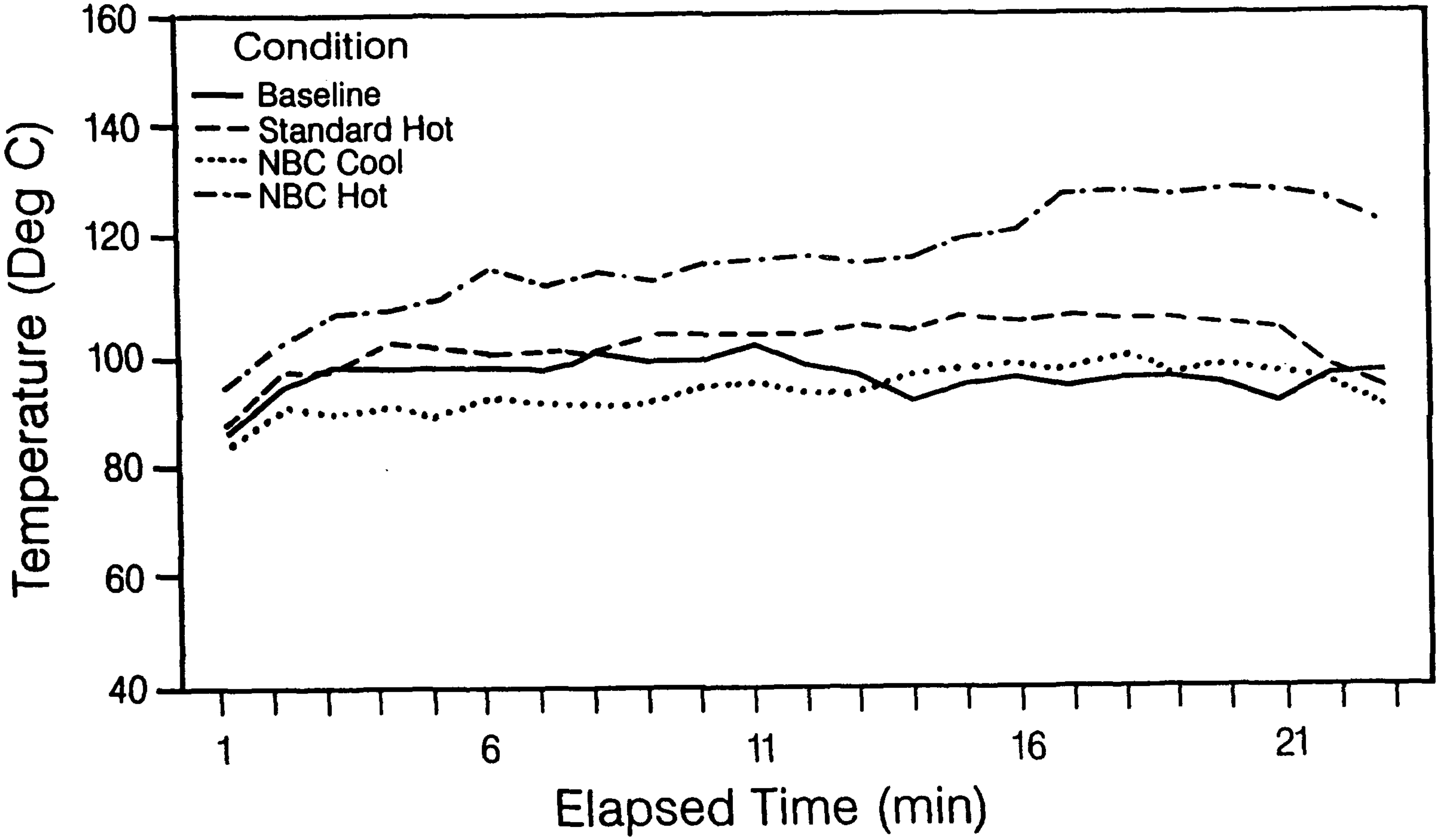

Figure 39. Heat rate during treadmill.

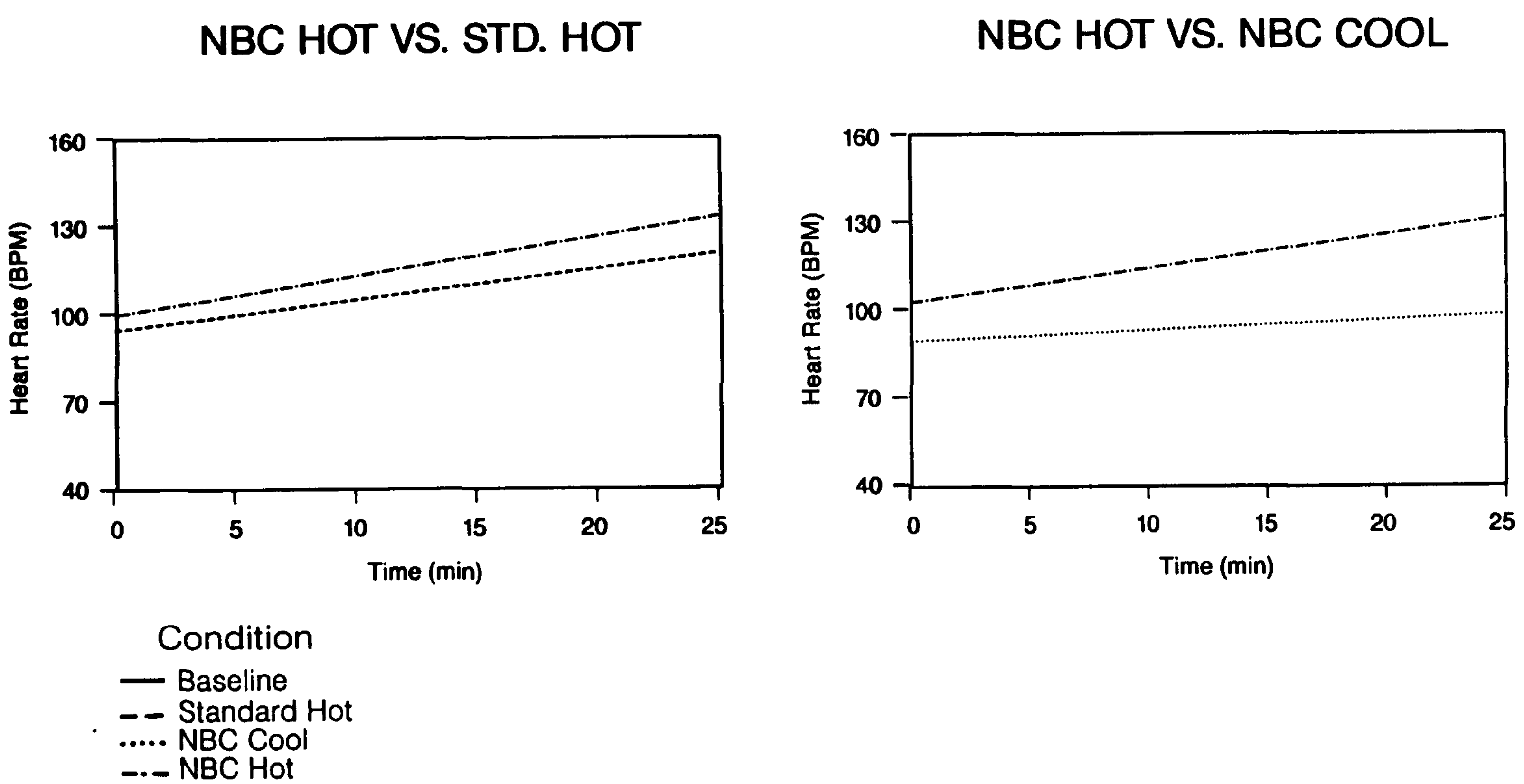

Figure 40. Heart rate confidence intervals during treadmill.

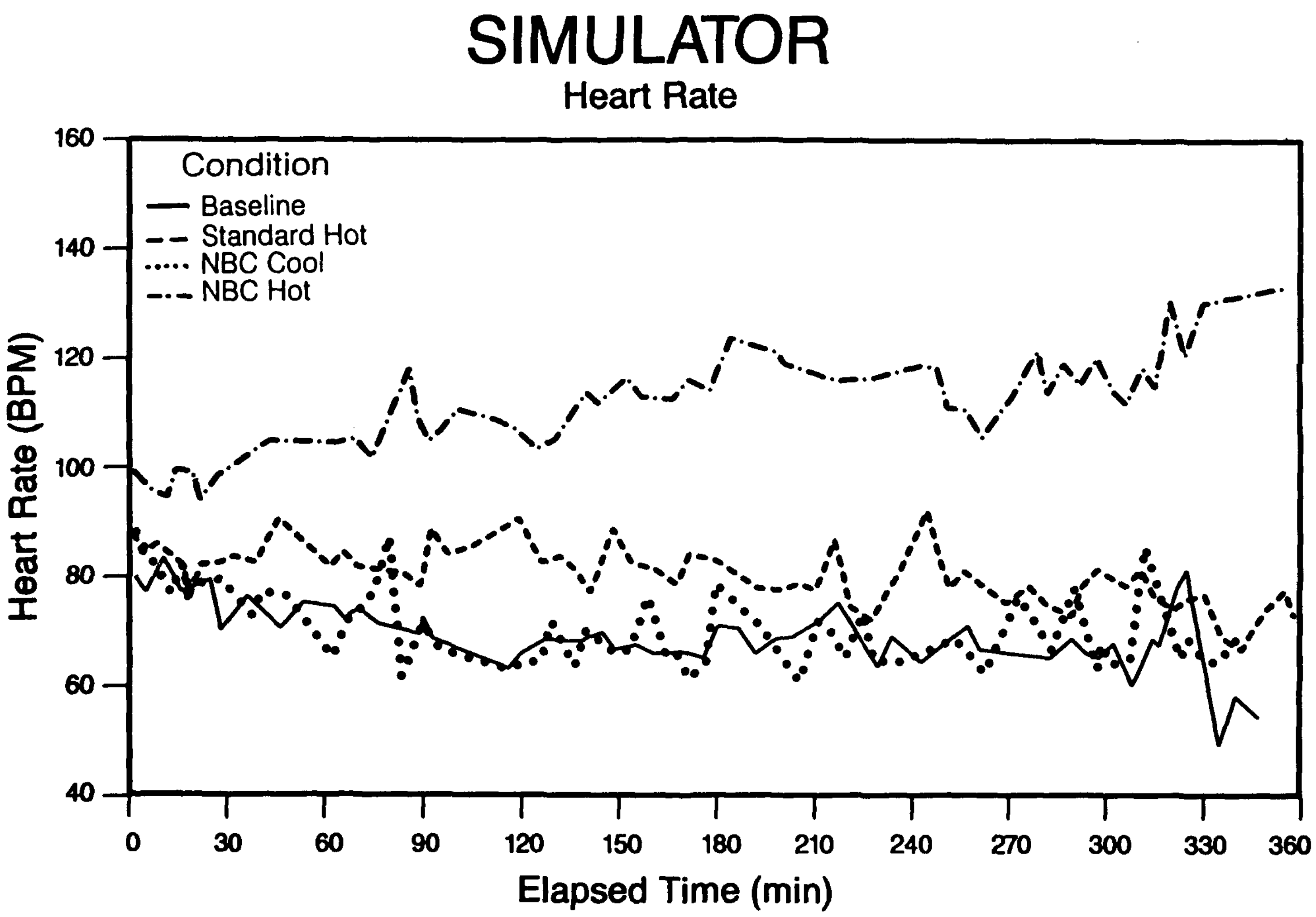

Figure 41. Heart rate in simulator.

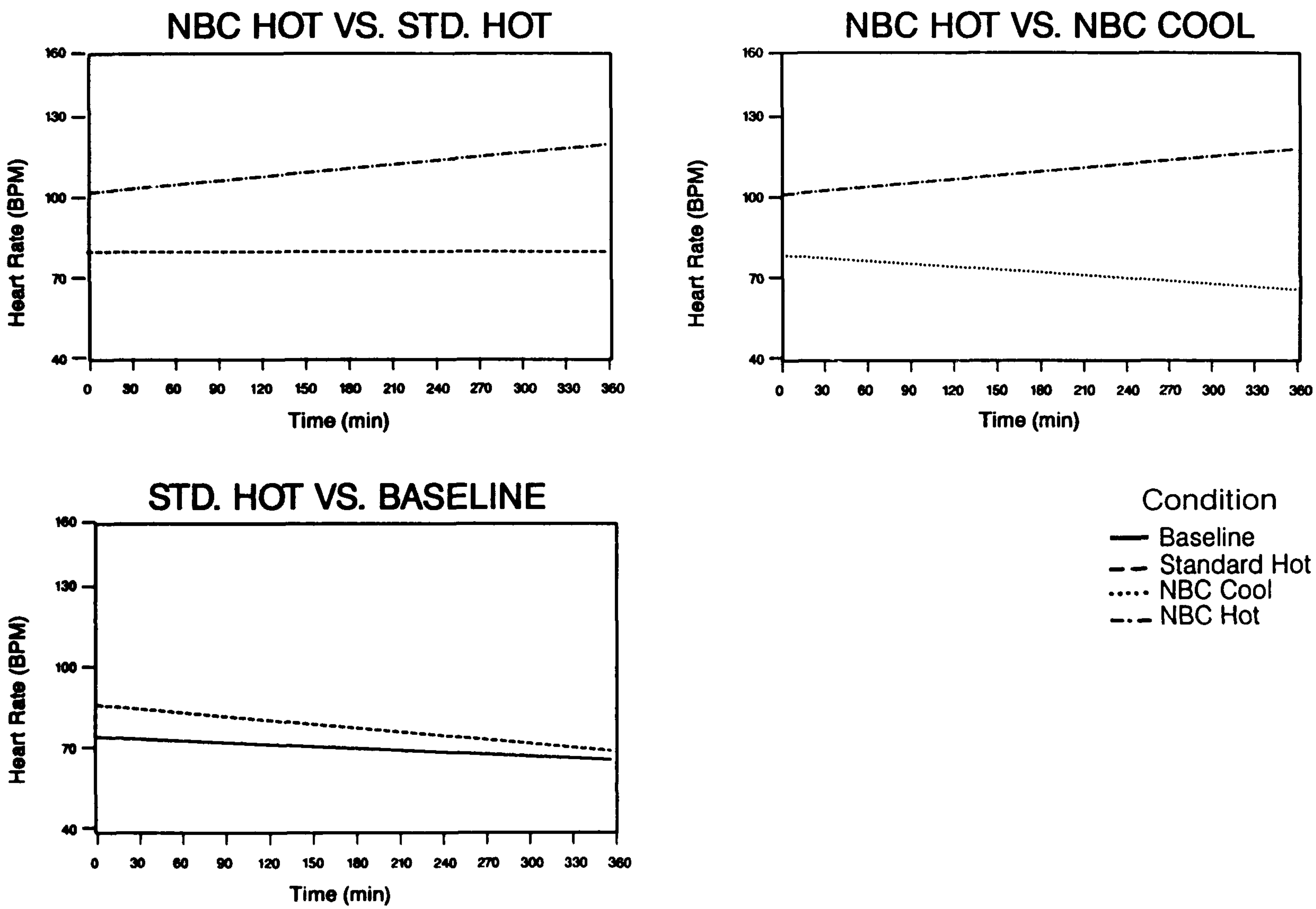

Figure 42. Heart rate confidence intervals in simulator.

Water balance

Figure 43 graphs the water balance data in terms of weight (kg) for dehydration, sweat loss, water drank, and urine voided. The same information is expressed in Figure 44 for dehydration and sweat loss by percentage of initial nude body weight. Figure 45 shows the data for dehydration and sweat loss as a rate.

Dehydration is present in all conditions to some extent. The degree of dehydration by weight and by percentage weight show significant main effects for condition ($F(3,45) = 4.00$, $p = 0.0334$ and ($F(3,45) = 4.00$, $p = 0.0322$), though the post hoc analysis showed no significant differences.

For sweat loss, the statistics for weight and percentage are the same. There is a significant main effect for condition ($F(3,45) = 38.87$, $p < 0.0001$ and $F(3,45) = 40.36$, $p < 0.0001$, respectively). The standard hot condition is significantly greater than baseline and cool NBC ($p < 0.0001$). NBC hot is significantly greater than all other conditions ($p < 0.0001$). For sweat loss by rate, there is again a significant main effect for condition ($F(3,45) = 17.82$, $p = 0.0006$). Standard hot is significantly greater than baaseline and cool NBC ($p < 0.001$), and greater than standard hot ($p < 0.01$).

The urine output showed no main effect for condition ($F(3,45) = 2.38$, $p = 0.1155$). In the NBC hot condition, only two subjects produced any urine at all, a total of 310 g.

The weight of water consumed showed a main effect for condition ($F(3,45) = 18.14$, $p < 0.0001$). It was significantly greater for standard hot versus baseline ($p < 0.0001$) and cool NBC ($p< 0.001$), and for NBC hot versus baseline and cool NBC ($p < 0.0001$).

Figure 46 presents the data for dehydration, sweat loss, and water drank during the hot NBC condition, separated into survivors and nonsurvivors. Because the exposure time to the heat for the nonsurvivors was less, these data are not as meaningful as the rate data in Figure 47. This shows a clear increase in all parameters for nonsurvivors against survivors. They are not significant statistically, however, despite an almost two-fold difference, because there is a very large variance in the data. The mean for sweat rate for nonsurvivors, for example, is 12.9 g/min, with a standard deviation of 10.7.

The summary statistics for water balance are in Table 27.

Table 27.
Summary statistics for water balance.

	Initial Wt (kg)	Dehydration Wt (kg)	Dehydration %	Dehydration Rate (g/min)	Sweat Loss Wt (kg)	Sweat Loss %	Sweat Loss Rate (g/min)	Drink Wt (kg)	Urine Wt (kg)
Baseline									
Mean	82.78	0.42	0.50	1.73	0.50	0.59	1.27	0.40	0.33
STD	9.24	0.63	0.74	2.60	0.30	0.34	0.78	0.37	0.53
Std hot									
Mean	82.53	0.50	0.58	2.45	1.54	1.88	3.96	1.33	0.28
STD	8.92	0.59	0.70	2.79	0.45	0.54	1.17	0.71	0.50
NBC cool									
Mean	82.63	0.52	0.62	2.52	0.70	0.82	1.78	0.49	0.32
STD	9.06	0.39	0.46	4.89	0.28	0.27	0.72	0.46	0.50
NBC hot									
Mean	82.55	1.11	1.31	5.22	2.63	3.18	9.87	1.54	0.02
STD	9.14	1.17	1.34	7.54	1.15	1.32	7.55	0.97	0.83

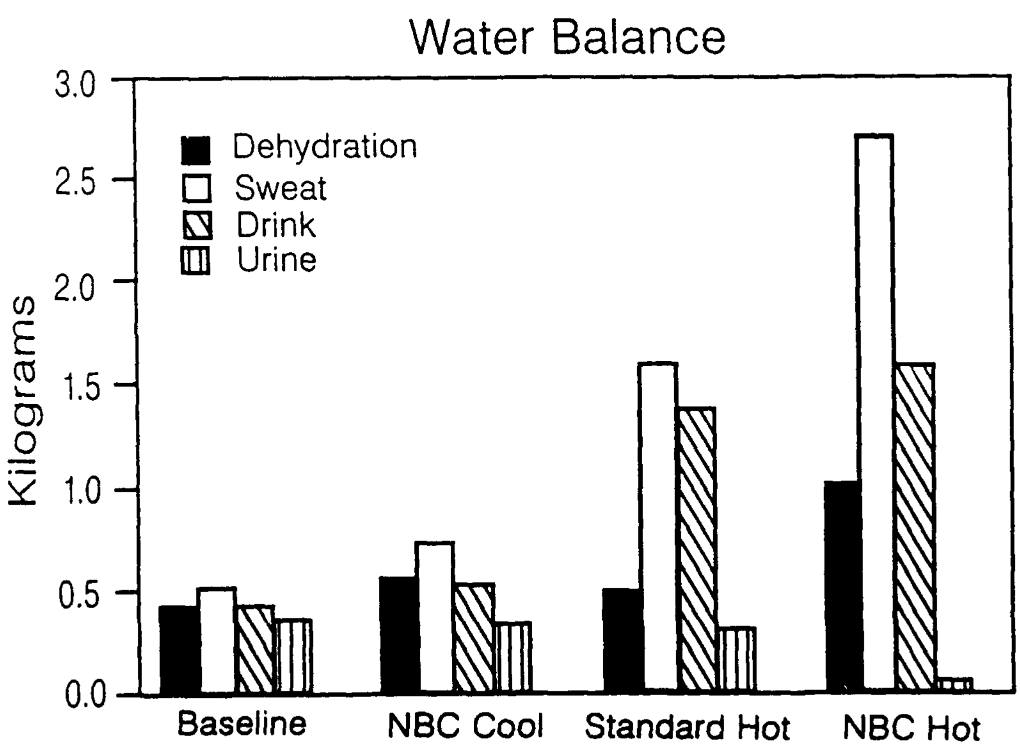

Figure 43. Water balance by weight.

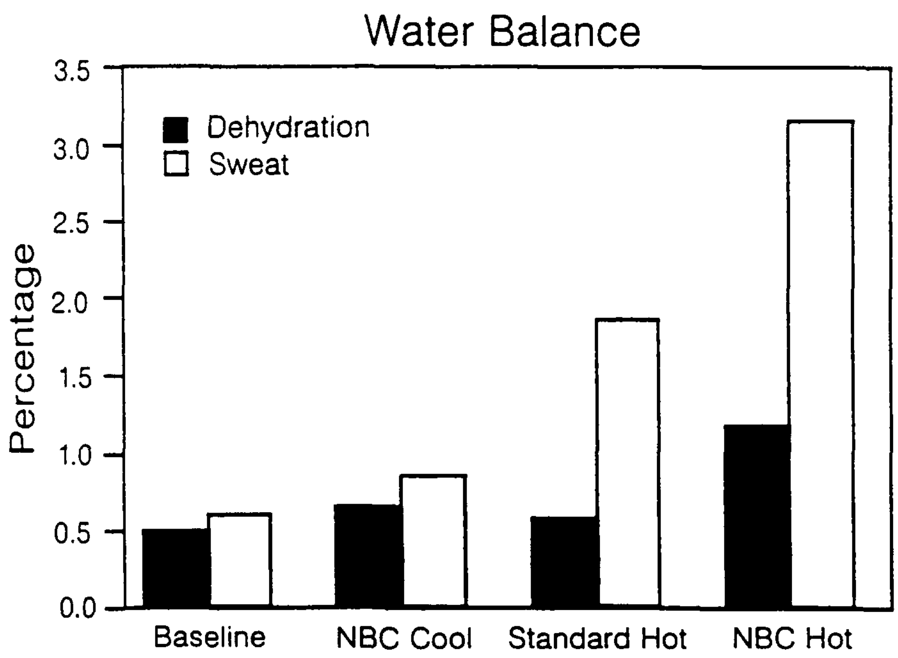

Figure 44. Water balance by percentage initial body weight.

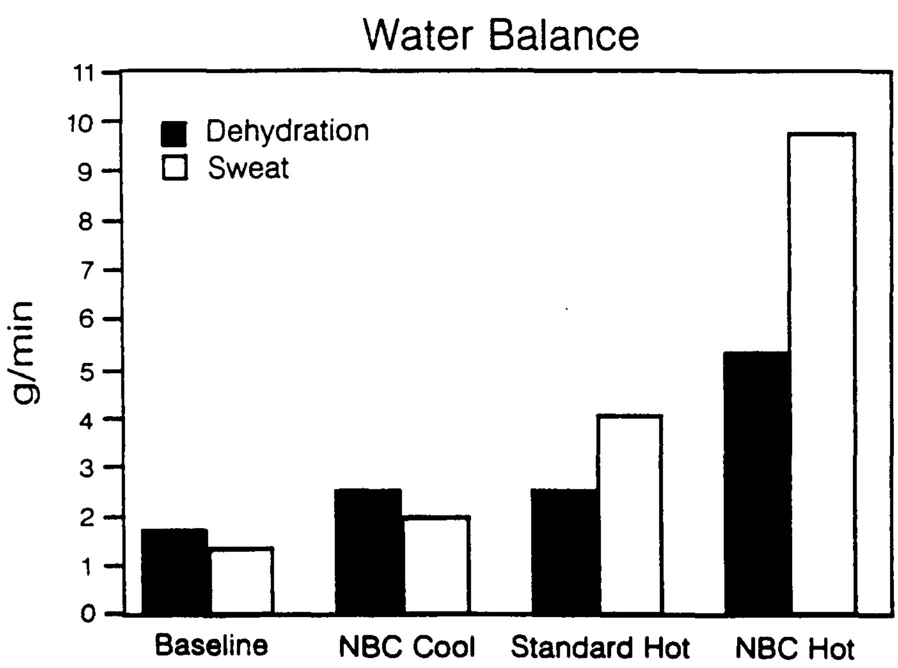

Figure 45. Water balance as a rate.

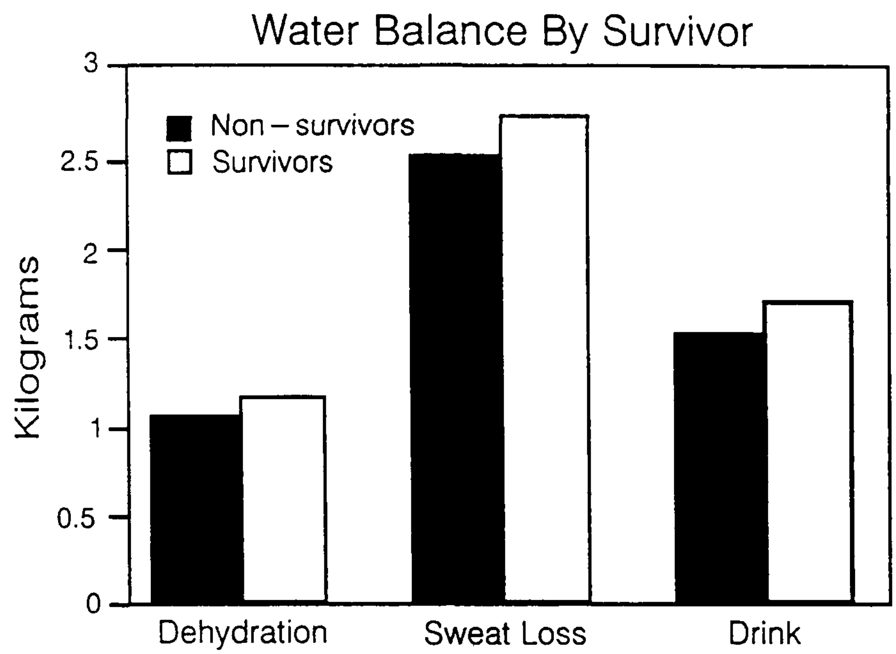

Figure 46. Water balance by weight, survivors against nonsurvivors.

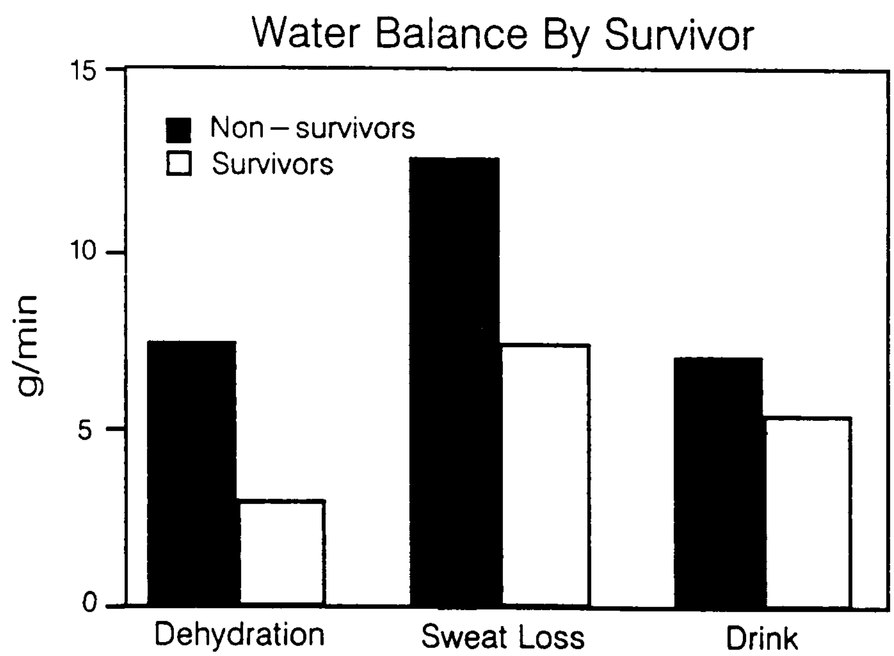

Figure 47. Water balance by rate, survivors against nonsurvivors.

Fatigue checklist

The mean scores for the fatigue checklist are plotted in Figure 48. Session one is the baseline, completed after dressing in the uniform of the day. Once the simulator flight was over, even if the subject retired early, no further checklists were completed. Therefore, on the NBC hot day, the result is a mean of survivors only. There was a complete set of data for only the nine subjects who survived the full six hours, and only they were included in the analysis.

There were significant main effects for day ($F(3,24) = 12.65$, $p < 0.0001$), and session ($F(3,24) = 16.77$, $p < 0.0001$). There was a significant interaction between day and session ($F(9,72) = 2.91$, $p = 0.0054$). The contrasts on session main effect showed a significant difference between sessions one and two ($p < 0.05$), between sessions two and three ($p < 0.001$), and between sessions three and four ($p < 0.05$).

The scores at the start of the day (session 1) cannot be separated statistically. By session 2, NBC hot was significantly worse than all other conditions ($p < 0.05$). At session 3, NBC hot remained significantly worse than baseline and NBC cool ($p < 0.01$) and standard hot ($p < 0.05$) and in addition, cool NBC had become significantly worse than baseline ($p < 0.01$). By session 4, the standard hot condition also was significantly worse than baseline ($p < 0.05$). NBC hot remained significantly worse than all other conditions ($p < 0.05$).

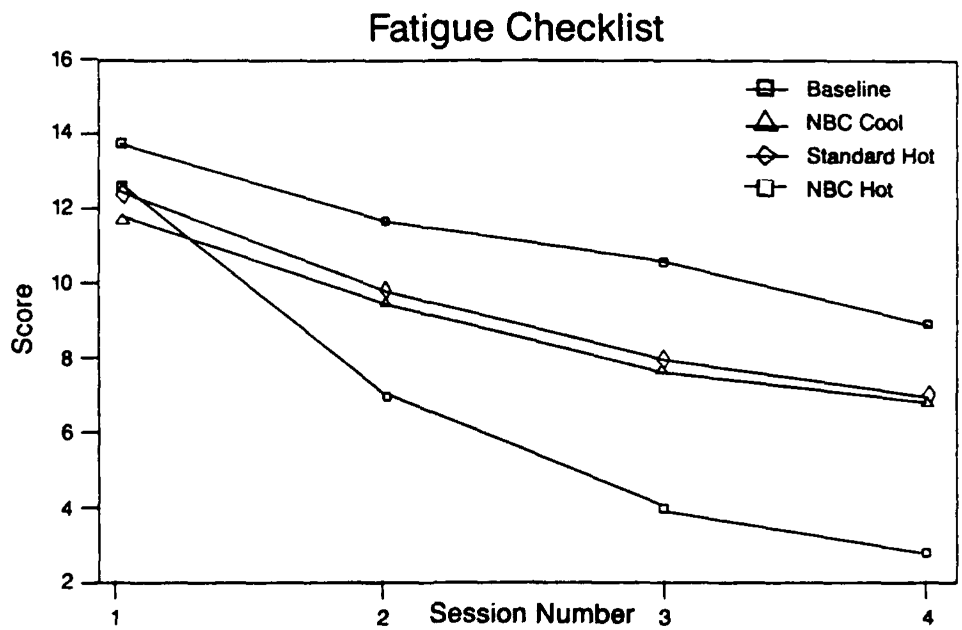

Figure 48. Mean fatigue checklist scores.

Performance assessment battery

Three measures from each PAB test were analyzed: number correct, reaction time, and throughput (a derived score indicating the number of correct responses per minute). Whenever the sphericity assumption was violated in the data, the Greenhouse-Geiser correction was used. In addition, alpha inflation in the posthoc contrasts was corrected for by using the Bonferroni adjusted probability levels. The results of each test are discussed separately.

Encode/decode (Griddle)

A main effect for session was found for both number correct ($F(2,26) = 3.49$, $p = 0.045$) and reaction time ($F(2,26) = 3.42$, $p = 0.048$). Posthoc analyses indicated that for number correct, the third session was significantly worse than the second session, with no differences between the first and second sessions or between the first and third sessions. No significant contrasts were found for reaction time.

Six-letter search (MAST-6)

A day by session interaction was found for both reaction time ($F(6,78) = 5.96$, $p < 0.0001$) and throughput ($F(6,78) = 6.91$, $p < 0.0001$). Further analyses indicated that reaction time was faster during the hot NBC condition than at the baseline condition during both sessions two and three. This effect also was evident in the throughput measure, which is derived from both the number correct and the speed of response. A main effect for condition was found in the reaction time and throughput measures, with posthoc tests indicating that the responses were faster in the hot NBC condition than in baseline.

Logical reasoning

A significant effect was found for condition in the throughput measure ($F(3,39) = 5.33$, $p = 0.004$). Posthoc analysis indicated that the baseline condition was slower than the hot standard condition, with no significant differences in any other conditions.

Digit recall

A main effect for session was found for number correct ($F(2,26) = 9.40$, $p = 0.001$), reaction time ($F(2m26) = 4.76$, $p = 0.017$), and throughput ($F(2,26) = 20.29$, $p < 0.0001$). Posthoc tests indicated that for the number correct, subjects were significantly worse in session three than in both sessions one and two. In addition, subjects were significantly faster in session one than in either session two or three.

Serial addition/subtraction

A main effect for condition was found for throughput ($F(3,39) = 4.30$, $p = 0.01$), however, posthoc tests were not significant. A main effect for session also was indicated for both reaction time ($F(2,26) = 3.74$, $p = 0.037$) and throughput ($F(2,26) = 5.18$, $p = 0.013$), with posthoc tests indicating that session three was significantly slower than session one.

Matrix I

No significant effects were found for any of the measures in the matrix test.

Wilkinson four-choice reaction time

A significant main effect was found for condition for both reaction time ($F(3,39) = 4.44$, $p = 0.009$) and throughput ($F(3,39) = 4.51$, $p = 0.008$). Posthoc tests indicated that the hot NBC condition had better performance than the baseline condition.

Environmental temperature

The temperatures recorded in the simulator cockpit and in the treadmill room are shown in Table 28. The temperatures in the treadmill room were as hot as could be achieved with the use of space heaters, and showed considerable variation, related to the outside air temperature and the efficiency of the Laboratory's air conditioning system. The simulator temperatures were much more consistent. The recorded temperatures were slightly higher than those selected on the simulator ECS, due probably to the differing positions of the Wibgets and the ECS sensors.

Postflight questionnaire

The postflight questionnaire was used to obtain subject opinions of human factors aspects of wearing the two clothing assemblies. A detailed analysis appears in Appendix I.

They were first asked to rate how easy or difficult it was to perform the various activities that make up flying the aircraft, on a seven-point scale, where one was very difficult, and seven very easy. In NBC IPE, the view inside the cockpit received the lowest (i.e., "worst") scores. Items involving manipulation received scores indicating slight difficulty, as those related to reaching around the cockpit. Manipulating t foot pedals also was reported to be slightly difficult. Ther was little difference between the cool and hot NBC condition: There were no particular problems reported in the non-NBC conditions, except that in the heat, the scores for all ques' tended to be reduced slightly, especially for reach and sitt

Table 28.
Environmental temperatures ($^{\circ}$C)
(mean and standard deviation).

Treadmill	Dry bulb	Wet bulb	WBGT
Hot	32.1 (1.67)	18.8 (1.61)	22.7 (1.33)
Cool	21.9 (1.02)	15.7 (1.98)	17.8 (1.48)
Simulator	Dry Bulb	Wet Bulb	WBGT
Hot	35.9 (0.30)	27.8 (0.42)	30.6 (0.51)
Cool	21.6 (0.30)	15.7 (0.46)	17.9 (0.38)
Training	23.1 (1.43)	16.0 (1.62)	18.3 (1.44)

The effect of the components of the uniforms on four specific aspects of performance was assessed on a five-point scale where zero was not at all impaired, four extremely impaired. Any ratings of one or higher required subjects to explain in more detail. For seeing inside the cockpit in NBC IPE, the mean score for the mask and hood indicated moderate impairment as did that for the survival vest and armor. No problems were reported in the non-NBC conditions. Manipulati the primary flight controls was impaired slightly by the NBC overboots due to reduced ability to feel the pedal microswitc For manipulating other controls and switches, the NBC gloves blamed due to reduced manual dexterity, and the mask and hooc because of a reduction in neck mobility caused by the mask hc Similarly, the ability to move the body and arms to reach controls was said to be impaired for the same reasons. The SARVIP/armor combination also was criticized in this regard the non-NBC case by four individuals.

Section three addressed other compatibility issues relating to specific items of equipment. Four subjects complained of difficulty in using the M43 mask drinking tube. Five related problems fastening the seat restraint harness in NBC IPE. Nine complained of difficulty in reading hand-held material when wearing the mask, five specifically referring to the limitation on neck flexion. Ten subjects complained about the interaction between the hose of the M43 mask and the SARVIP, causing restriction of neck flexion.

Heat stress was assessed for each of the three sorties of the day using a five-point scale in which zero was not at all hot, four extremely hot. On the NBC hot day, the score rose from 2.3 for the first sortie to 3.6 for the last. On the NBC cool day, six subjects complained of feeling slightly hot on all three flights. On the standard hot day, the mean rating was 1.6 for all flights.

A similar scale was used to rate the importance of the effect of being hot on the ability to fly, and was repeated for each individual item. The scores were similar to the previous case for the overall effect of being hot on flight performance. The mask received the highest score in the NBC hot condition for its importance in making the subjects feel hot, closely followed by the suit. The helmet and overboots also were scored as being a moderate contribution to the problem.

Fit or comfort of the various components of the ensemble was assessed by asking for 'yes' or 'no' responses, with space for explanation. There were no consistently reported complaints.

In the last section, the subjects were asked to rate the overall acceptability of the flight uniform using a seven-point scale. One was very unacceptable, seven was very acceptable. The mean score was 4.1 on the NBC cool day, indicating a neutral response, and 3.5 for the NBC hot condition, which is just unacceptable. The majority of subjects however rated it unacceptable in some degree (10) with only 6 giving it a neutral or acceptable rating.

Finally, they were asked to list the worst problem associated with the equipment and suggest solutions. There was no general agreement, and four subjects in each case listed overheating, field-of-view, and mask hose/SARVIP interaction as causing the most concern. Five individuals indicated that microclimate cooling was the solution to the problems, four suggested that the mask hose attachment should be moved to where it would not interact with the SARVIP, and four subjects wanted an increase in the mask viewing area.

A clothing problem that was not picked up on the questionnaires, because it occurred before flight, was caused by the NBC overboots. These are slightly higher than the combat boot, and have a stiff, sharp upper border which rubbed on the shins of the subjects while they were walking. This was painful and caused significant abrasions in many cases. It was treated in a variety of ways, by padding the edge with mole skin, leaving the top fastener undone, and even cutting away the tongue of the boot.

Discussion

Flight performance

Test conditions

There were nine basic maneuvers flown in the standard flight schedule. In all of them, there was at least one parameter in which the RMS error was statistically higher in the NBC hot case than at least one of the other three conditions. The 9 basic maneuvers, after subdivision into high and low hover and AFCS in or out, produce 14 individual submaneuvers. For 11 of these, the error rate was greater for one or more parameters in the hot NBC condition. If the 55 combinations of maneuver number and parameter are considered, there were 21 instances in which the NBC hot condition produced statistically greater errors.

Whichever way it is considered, the flight performance in the NBC hot case was clearly worse than in the others. By contrast, NBC cool produced only 4 of 55 maneuver parameters in which the RMS error was significantly greater than one of the other conditions. The baseline condition had a greater error in two cases, and standard hot had no examples of significantly greater error.

Exposure time

The effect of exposure time on performance was tested by comparing performance data for the three flights. When the data were collapsed across condition, there were just 2 examples, from a possible 55 cells, when the second and third flights produced significantly greater errors than the first. There was also one example of the second flight producing significantly greater errors than the first flight, and one in which the error in the second was greater than the third.

When the same analyses were done for the NBC hot data alone, there were two examples of the third flight having a significantly higher error rate than the first and second. There were three cases in which the third flight produced a significantly greater error than the first flight. The second flight had significantly higher error rates than the first and third in two cases, and there was one case in which the error during the second flight was significantly greater than in the first only.

In total, there were 8 examples of a significant difference between flights, out of a possible 55.

It is suggested, therefore, that despite the steady increase in rectal temperature during flight, the effect on flight performance is not directly related, but is an all or nothing phenomenon which is present even at the start of the flight and does not get appreciably worse. What is not known is what would happen to the flight performance of those who did not complete the protocol, if they had been made to continue flying, as would presumably be the case in the real situation.

Operational interpretation

The fact that there is inconsistency in the results, in that not all maneuvers, nor even all parameters within the same maneuver, were equally affected, indicates that the effect on flight performance of wearing the NBC IPE in moderately hot conditions is not an extreme one. In an operational context, the levels of performance error produced would not normally constitute a danger to flight safety. The results described are, however, RMS errors, and give no indication of the maximum error made for a particular maneuver, which to the operational pilot might be more relevant. For example, the mean RMS error for altitude during navigation for all subjects in the NBC hot condition was 20.79 ft. The maximum individual error for any one subject was 228 ft, and the mean maximum error, 49 ft. These values, which appear as tables for each maneuver, would be of more interest to the operational community than the RMS errors. In flight, the aberrational occurrence of extremes of flight performance can be much more significant in its consequences than an overall performance decrement.

A further factor of importance in interpreting the practical consequences of this level of performance impairment is that performance was not scored for the entire duration of the flight, but for discrete segments. Scoring began for individual maneuvers only when the pilot had brought the simulator within certain constraints, i.e., they were already settled into the maneuver before scoring began. The actual point at which scoring began was determined by the appropriate algorithm in the scoring program or by the simulator instructor/operator, depending on the maneuver concerned. The time taken to get within the appropriate parameters might be expected to vary with condition, though that was not recorded. Similarly, flight performance may have shown greater variation with condition during portions when the aviators knew they were not being scored.

The ultimate test of poor flight performance is to count the number of times the simulator crashed. Six of the seven crashes recorded were in NBC IPE, four cool and two hot. All were caused by flight into terrain during low level flight or hitting trees in the hover. This suggests that the restriction of head movement caused by the M43 mask hose's interaction with the SARVIP may have caused problems with lookout or with dividing attention between the outside visual scene and vital cockpit instruments, such as the radar altimeter.

Intersubject variation

One of the problems in analyzing the flight performance data is the large degree of intersubject variation. There was only one maneuver parameter in which there was no significant difference between subjects. Typically, the Duncan analysis grouped the subjects into four or five significantly different sets for each maneuver parameter. There was little consistency in the assignment of subjects to sets for the various maneuver parameters, and there were examples of the same subject having the greatest error for one maneuver parameter, and the lowest for another.

Sensitivity

An assessment of the number of positive and negative results for the seven individual parameters, shown in Table 9, indicates that heading and vertical speed (rate of climb or descent) are the only consistently sensitive indicators, and slip is a particularly insensitive one. Of the maneuvers, high hover, low hover turn, and left standard rate turn (AFCS in) were the only 3 of the 14 to be completely insensitive to the effects of condition. Conversely, descent was the only maneuver which produced significant results for all parameters. Left standard rate turn (AFCS out) was sensitive in four out of five parameters.

The effect of flying without the AFCS was considered by comparing the number of significant results for the three maneuvers that were flown with and without the AFCS (right standard rate turn, left standard rate turn, and straight and level). With the AFCS in, there were 4 significant results from the 15 parameters, with AFCS out, there were 11. Descent was flown only with the AFCS out, and produced significant results for all five parameters. Put another way, without the AFCS out maneuvers, there would have been significant results for only 9 maneuver parameters, when there were in fact 26.

Training

Five days were allowed for training, half in normal flight suit, half in NBC IPE. There is evidence of improvement in performance for the first one or two flights for most maneuvers, but none thereafter. There is little evidence of detriment in performance on donning NBC IPE. Therefore, in retrospect, the amount of training time allocated was far too generous. A maximum of 4 hours of training for each pilot would ensure adequate familiarization with a flight profile of this degree of difficulty.

Flight profile

The flight profile was not particularly taxing for the skills of the pilots, as shown by the speed with which they achieved asymptote during training. It consisted of routine flight maneuvers only, with no real emergencies (other than failing the AFCS), no unexpected events, and no enemy threat. It was the result of a compromise between the demands of real world combat flight and the restrictions which had to be imposed in order to allow accurate objective comparisons of different conditions. The results should, therefore, be considered conservative, in that the real world would be expected to produce more significant decrements in performance.

Conversely, low level flight in the real aircraft produces better situational awareness than simulated flight. The visual system in the simulator does not give sufficiently accurate height clues near to the ground, and the consequences of crashing bear no comparison. Therefore, it is unlikely that the seven crashes which occurred in the simulator would have happened in the aircraft.

Physiology

There was a considerable rise in rectal temperature in the NBC hot condition compared to the other three, and a much smaller, though still significant rise for standard hot. The treadmill exercise made a small, but significant contribution to the overall temperature rise. The rise for the NBC hot condition was diluted by the effect of runs being terminated, for either physiological or subjective reasons, by seven subjects.

If the nonsurvivors are considered separately as a group, their forced stay in the hot conditions, which would have occurred in an operational situation, would have resulted in them becoming heat casualties. They then would have had to abort their mission to prevent serious injury or continue until they became casualties from the heat or an aircraft accident. None of the demographic factors recorded, such as weight, age, or experience were of any value in predicting survivors.

The mean skin temperature rose slowly for both hot conditions, and there was only one case in which it came within

0.5°C of the rectal temperature. The heart rate continued to rise in the hot NBC condition throughout the day and did not show the plateau effect the rectal temperature demonstrated. This suggests that even the survivors were under increasing stress and eventually would have failed. No individual subject reached the 150 bpm limit for withdrawal.

Most subjects became significantly dehydrated in the NBC hot condition, with a mean weight loss of 1.1 kg, which represented 1.3 percent of body weight. This level of dehydration is associated with a reduction in physical work capacity (Saltin, 1964), and would be a significant factor in any survival situation. The associated reduction in plasma volume also would limit tolerance to other cardiovascular stressors, such as increase in g in a higher performance helicopter. As with temperature, continuing exposure to the same conditions would eventually lead to severe dehydration. The fact that the degree of dehydration is so much greater for the NBC hot condition than the standard hot suggests that the rate at which water can be consumed through the M43 mask drinking tube is inadequate to maintain hydration. Despite a much higher sweat rate in NBC hot, the mean water consumption was little higher than for standard hot.

A factor in establishing why the nonsurvivors did not last the full 6 hours might be their inability to maintain hydration as well. There is little difference in the total weight of water consumed by the two groups, but the non survivors actually drank at almost twice the rate of the survivors. The non-survivors also sweated at twice the rate of the survivors, but this may have been in response to their higher rectal temperatures.

Performance assessment battery

The results from the PAB analysis indicated that as time progressed in the flights, performance declined. This decline was seen mainly in the speed of response, with accuracy remaining fairly high. An unexpected result was that on most tests, the baseline condition had the lowest performance compared with the other conditions, usually with the hot NBC condition having the best performance. One reason that the baseline condition was lowest may be that this condition always occurred first in the sequence, with the other conditions being counterbalanced. Even though subjects should have stabilized in performance after the training sessions, 2 days elapsed between the baseline condition and the last training day. Although this time lapse is short, it may have been long enough to cause a short learning curve once the tests were administered again.

The reason the hot NBC condition generally had the best performance of all the conditions is unknown. Several effects of heat on performance have been reported in the literature. Impairment in performance, no change in performance, and improved performance have all been seen in studies evaluating the effects of heat stress (Kobrick and Johnson, 1988). Some of the tasks in the present study followed a pattern of initial improved performance, followed by a slight decline in performance as time passed. This effect has been reported in other studies (Fine and Kobrick, 1978). However, no clear effect of heat on performance has been determined.

The discrepancies in the literature may be due to the various tasks used in each of the studies, the different environmental conditions, and the amount of training on the tasks. Performance is affected by these factors with heat interacting with each of the variables. The exact tasks which are likely to be impaired by heat are not known. In addition, many variables affect performance in stress conditions, such as motivation, acclimatization, training, and experience level. The interactions of these variables with heat still have not been adequately determined.

Postflight questionnaire

The results of the postflight questionnaire relate mostly to the difficulties experienced due to a restriction of head movement. This is caused partly by the weight of mask hose which must be dragged around whenever the head is moved, but more seriously because of an interaction which occurs between the hose near its attachment to the mask, and the bulk of the armor/SARVIP combination. The hose is attached to the mask in such a way that it points downwards (Figure 3), and the proximal portion is stiffened so that when it comes into contact with the SARVIP, neck flexion is limited. This caused a number of complaints about the difficulty of viewing areas inside the cockpit, and resulting neck fatigue. The majority of subjects rated the NBC ensemble as unacceptable in some degree.

Conclusions

When reading the conclusions of this study, it must be borne in mind that the conditions were by no means worst case. The flight profile was undemanding and well rehearsed, and the environmental conditions, while stressful, were not particularly hot, and are regularly exceeded in most current theaters of operations. Furthermore, the AUIB is not yet in service, and the current NBC IPE can be expected to produce a greater heat load.

1. Flight in NBC IPE in the heat produced a moderate, but statistically significant impairment of flight performance. There was some evidence of impairment in the NBC cool condition.

2. Flight performance showed little decrement with increasing time in the environment, up to the 6 hours tested.

3. There was a considerable degree of variation in the magnitude of error between subjects.

4. There were six crashes in NBC IPE, but only one in the standard flight ensemble.

5. The performance assessment battery was insensitive to the effects of clothing and environment, but showed significant impairment with time for all conditions.

6. Individuals experienced a significant degree of fatigue in all conditions but the control; the worse condition was the NBC hot condition. In all conditions, they became increasingly fatigued with time.

7. All subjects experienced a significant degree of heat stress in the NBC hot condition with increased rectal temperature, mean skin temperature, and heart rate.

8. A significant degree of dehydration was experienced in the NBC hot condition.

9. Seven subjects failed to complete the standard flight profile in the NBC hot condition, with a mean survival time reduced by 62 minutes compared with the other conditions. The minimum survival time was 60 minutes.

10. There is a significant problem with interaction between the hose of the M43 mask and the SARVIP which causes interference with head movement.

11. The NBC overboot causes painful abrasions of the shins.

Recommendations

1. Flight in NBC conditions in hot weather poses a significant threat to flight performance and safety. Commanders should be aware of the risks and plan their NBC training accordingly.

2. An important factor in the degree of heat stress is the amount of preflight exertion. This should be kept to a minimum by such measures as avoiding walking to the aircraft and preflighting.

3. The development of microclimate cooling for aviators is essential to allow operational use of NBC IPE in all but the coolest of temperature conditions.

4. Consideration should be given to increasing the flow rate of the M43 mask drinking tube.

5. The compatibility between the M43 mask and the SARVIP should be improved.

6. The NBC overboot should be shortened.

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Appendix A.

Subject briefing letter

THE PHYSIOLOGICAL EFFECTS OF WEARING THE AIRCREW UNIFORM INTEGRATED BATTLEFIELD (AUIB) WHILE FLYING THE UH-60 SIMULATOR IN A CONTROLLED HEAT ENVIRONMENT

Name ____________________ Rank ___

Unit ____

Trial dates _________________

Thank you for volunteering to take part in the USAARL study on the effects of the Aircrew Uniform Integrated Battlefield (AUIB) on flying performance. The aim of the trial is to assess the new aviator CD uniform (the AUIB and M43 mask) in the UH-60 aeromedical simulator, in both cool and hot conditions. It will take two working weeks to complete and you will be flying for up to 6 hours per day, alternating duties between pilot and copilot. You will fly a maximum of 44 hours total, and will cover all the usual emergencies with an IP.

The USAARL UH-60 simulator is an aeromedical version of the standard training simulator, with the addition of a system which can be used to control cockpit temperature and humidity. You will be flying in cool and hot conditions, both with and without NBC equipment, and can expect to log up to 60 simulator hours, depending on how long it takes you to train on the particular flight profile we have devised. You will need your own standard flight helmet, boots, gloves, kneeboard, at least three flight suits, and your personal undergarments. We will supply undergarments for use with the AUIB in order to protect your own. You should also bring your medical records.

The simulator is instrumented to enable accurate measurement of flight parameters, and will be used in conjunction with several computer-based tests to measure the effect of the AUIB and heat on your performance. Other factors affecting performance can obviously interfere with the experiment, and so we will be inviting you to ensure that you get a good night's sleep each day, and refrain from alcohol and caffeine containing beverages for the duration of the experiment.

At the beginning of each day, you will be instrumented to record your temperature and heart rate, both to gain experimental data, and to make sure that you do not exceed rigidly designed parameters which are written into the protocol to ensure your safety. Your core body temperature will be measured using a rectal probe. A trained medical monitor will be with you in the simulator at all times to observe your core temperature and ensure your well-being. A flight surgeon will be on immediate standby should any problem arise. You may, of course, terminate the trial yourself at any stage should you develop any subjec· symptoms which make you feel you cannot continue, such as excessive headache or nausea.

You will be allowed free access to water during the fligh through the M43 drinking tube on the NBC days, but you will nc be able to eat, so have a good breakfast. We will provide you with a light lunch on completion of flying, and can give you breakfast if necessary.

Records of the trial will not identify you by name nor wi you be identifiable in any subsequent report. The aim is to present group data showing how large numbers of aviators perfc .

Your participation in this trial is very important to the Army and to our aviation community in particular, thus we hope you will always perform your best throughout the trials. You will undoubtably learn more about yourself and your ability tc perform in such conditions as we are studying, and you will be contributing to our knowledge of how best to design equipment procedures for flying in chemical threat environments.

You should report to the CQ desk at USAARL at 0730 on 15 April. If you develop any medical problems, or you have any questions in the meantime, please contact LTC Robert Thornton, at AUTOVON 558-6846, or CPT Wayne Clark at AUTOVON 558-6871.

ROBERT THORNTON, MD
LTC, RAMC
Research Flight Surgeon

Appendix B.

Timetable

TIMETABLE

Week One

Day	Time	Activity	Responsible
Monday	0745	Arrive USAARL	SSG Rosario
	0800	Subject briefing	LTC Thornton
	0830	PAB training	SGT Burke
	0930	Simulator briefing	CPT Clark
	1000	Flight 1	CPT Clark
	1200	Debriefing	CPT Clark
	1230	LUNCH	
	1330	PAB Training	SGT Burke
	1400	Flight 2	CPT Clark
	1630	END	
Tuesday	0745	Arrive USAARL	SSG Rosario
	0800	PAB training	SGT Burke
	0830	Flight 1	CPT Clark
	1030	Debriefing	CPT Clark
	1100	PAB training	SGT Burke
	1200	LUNCH	
	1300	Instrumentation	SGT Guardiani
	1330	Flight 2	CPT Clark
	1530	PAB training	SGT Burke
	1600	END	
Wednesday	0745	Arrive USAARL	SSG Rosario
	0800	Instrumentation	SGT Guardiani
	0830	PAB training	SGT Burke
	0900	Flight 1	CPT Clark
	1100	Treadmill training	SGT Guardiani
	1130	LUNCH	
	1230	AUIB dressing	SGT Guardiani
	1330	Flight 2	CPT Clark
	1530	PAB training	SGT Burke
	1600	AUIB off - END	

Day	Time	Activity	Responsible
Thursday	0745	Arrive USAARL	SSG Rosario
	0800	Instrumentation	SGT Guardiani
	0815	AUIB dressing	SGT Guardiani
	0830	Rest/PAB	SGT Burke
	0900	Flight 1	CPT Clark
	1100	Flight 2	CPT Clark
	1300	END	
Friday	0745	Arrive USAARL	SSG Rosario
	0800	Instrumentation	SGT Guardiani
	0815	AUIB dressing	SGT Guardiani
	0830	Rest/PAB	SGT Burke
	0900	Flight 1	CPT Clark
	1100	Flight 2	CPT Clark
	1300	Flight 3	CPT Clark
	1500	END	

<u>Week Two</u>

Mon-Fri	0745	Arrive USAARL	SSG Rosario
	0800	Instrumentation	SGT Guardiani
	0815	Dressing	SGT Guardiani
	0830	Rest/PAB	SGT Burke
	0900	Treadmill	SGT Guardiani
	0930	Simulator	CPT Clark
	1530	Undressing	SGT Guardiani
	1545	Questionnaire	PVT Polakis
	1615	END	

Appendix C.

Fatigue checklist

Fatigue checklist

Instructions

The statements which follow are to help you decide how you feel at this time - not yesterday, not an hour ago - but right now. For each statement you must determine whether you feel (1) "Better that", (2) "Same as," or (3) "Worse than" the feeling described by that statement.

No	Better than	Same as	Worse than	Statement
1	( )	( )	( )	very lively
2	( )	( )	( )	extremely tired
3	( )	( )	( )	quite fresh
4	( )	( )	( )	slightly tired
5	( )	( )	( )	extremely lively
6	( )	( )	( )	somewhat fresh
7	( )	( )	( )	very tired
8	( )	( )	( )	very refreshed
9	( )	( )	( )	quite tired
10	( )	( )	( )	ready to drop

Appendix D.

Simulator flight profile

Aircrew mission briefing

Navigation

1. Situation

   a. Threat: Warsaw Pact motorized rifle regiment

   b. Friendly units: 1 Mech infantry company (-), 2 ADA companies (+), 1 USAF TAC fighter squadron (-).

   c. Attachments and detachments: H & C Companies (-), 4th CAB, 19th Armored Division

2. Mission

   Direct support of Combat Operations requiring external load and tactical doppler navigation.

3. Execution

   a. Mission type: External load & Doppler NAV

   b. Authorized conditions: VMC/VHIRP

   c. Authorized flight modes: Low Level - 600'/700' MSL

   d. Movement techniques: Tactical with appropriate coordination with supported unit.

   e. Aircraft tail number: 82-23748
      Crews: Pilot______________________________
      Copilot______________________________

   f. Special mission equipment: 2 M60Ds with 2,000 rounds of 7.62 mm

   g. Authorized loads: Cargo - concrete block, ammunition - as stated.

   h. Flight route: Takeoff at H hour local from the Marshalling LZ (H), vicinity VK 85894439 and proceed to the abandoned airfield at WK 15966478. Place the prepositioned concrete block on the runway intersection to temporarily deny the enemy's use of the airfield as a forward emergency landing area and return to base. Plan your route of flight to pass the following air check points (ACP) at the prescribed times (+/-) 1 minute:

ACP	Location	Time	Course to
1	VK 85595130	H+03	018 Degrees
2	VK 90445447	H+05	079 Degrees
3	WK 06425546	H+10	106 Degrees
4	WK 09905188	H+12	152 Degrees
5	WK 09766449	H+16	018 Degrees
6	WK 15966478	H+20	106/289 Degrees*
5	(same)	H+33	106/289 Degrees*
4	(same)	H+37	199 Degrees
3	(same)	H+39	332 Degrees
2	(same)	H+44	286 Degrees
1	(same)	H+46	259 Degrees
H	(same)	H+1+00	198/018 Degrees*

*Note: The western noundary of the airfield is a no fly area for a 3-kilometer radius. Plan to approach the airfield on a 20 degree heading. Depart using the same corridor in the opposite direction.

**Note: Upon return, do not approach within 5 kilometers of the marshalling LZ (H) from the north due to preplanned friendly chemical strike. Inbound course is 270 degrees.

i. Mission restrictions: Friendly forces are weapons free throughout this time period and will engage any aircraft in the AO outside the predesignated air corridors. Flight route deviation is not authorized due to the extensive enemy and friendly antiair umbrella in the area of operations (AO).

j. Safety considerations: Checkpoints must be negotiated +/- 1 minute. In event of time schedule deviation, do not proceed. Land immediately and contact Flyswatter 76 on secure FM 38.6. Report position and stand by for departure routing and time out of AO. Only known wire hazard in the AO is between checkpoints 4 and 5. Recommend flight altitude of 700 MSL. Exercise caution when approaching roads or built up areas.

4. Service support.

a. Refuel/rearm location: VK 85894439

b. Ration support: Class B rations will be provided by the 4th CAB at the marshalling LZ.

c. Assembly area/bivouac. Remain overnight locations: marshalling landing area vicinity VK 85894439.

d. Maintenance support: As per 4th CAB Tactical SOP.

5. Command and signal.

a. Command: (1) Air Mission Commander________________
(2) Command or support relationship to supported unit: Direct Support (DS).

b. Signal (except for published frequencies): As per applicable CEOI and 19th AD TAC SOP.

6. Additional remarks.

a. Programming and use of Doppler for this mission are mandatory.

b. VHIRP procedures is climb to 3000 and contact Todendorf approach with approach requested.

c. Planning data:

GW: 13,850 lbs	PA: +5
Fuel: 1,925 lbs	OAT: +15
Wx: Clear, 3+ vis	Alt: 29.92
Flt Alt: 600' MSL	AS: 100 KIAS

AUIB protocol scoring

Navigation

Mark	Check pt	Maneuver	Parameter
1.	H	Hover	Heading 150° +/- 5° Altitude 10 AGL +/-3 ft
2.	H	Hovering turn	Heading 150° to 330° Altitude 10 AGL +/-3 ft
3.	H	High hover	Heading 330° +/- 5° Altitude 40 AGL +/-3 ft
4.	H	Hovering turn	Heading 330° to 150° Altitude 40 AGL +/-3 ft
5.	1	DA (Doppler/altitude)	Heading/Doppler +/- 10° ALT 600 MSL +/- 100ft Time 3 minutes +/-15 sec
6.	2	DA (Doppler/altitude)	Heading/Doppler +/- 10° ALT 600 MSL +/- 100ft Time 2 minutes +/-15 sec
7.	3	DA (Doppler/altitude)	Heading/Doppler +/- 10° ALT 600 MSL +/- 100ft Time 5 minutes +/-15 sec
8.	4	DA (Doppler/altitude)	Heading/Doppler +/- 10° ALT 600 MSL +/- 100ft Time 2 minutes +/-15 sec
9.	5	DA (Doppler/altitude)	Heading/Doppler +/- 10° ALT 700 MSL +/- 100ft Time 4 minutes +/-15 sec
10.	6 3 km	Doppler arc Landing 200°	Heading/Doppler +/- 10° ALT 600 MSL +/- 100ft Time NA (A/S <80 KIAS)
11.	5 3 km	Doppler arc	Heading/Doppler +/- 10° ALT 700 MSL +/- 100ft Time 4 minutes +/-15 sec
12.	4	DA (Doppler/altitude)	Heading/Doppler +/- 10° ALT 700 MSL +/- 100ft Time 4 minutes +/-15 sec

13.	3	DA (Doppler/altitude)	Heading/Doppler +/- 10° ALT 600 MSL +/- 100ft Time 2 minutes +/-15 sec
14.	2	DA (Doppler/altitude)	Heading/Doppler +/- 10° ALT 600 MSL +/- 100ft Time 5 minutes +/-15 sec
15.	1	DA (Doppler/altitude)	Heading/Doppler +/- 10° ALT 600 MSL +/- 100ft Time 2 minutes +/-15 sec
16.	H	Doppler arc 5 km Landing 270°	Heading/Doppler +/- 10° ALT 600 MSL +/- 100ft Time NA (A/S <80 KIAS)
17.	H	Hover	Heading 150° +/- 5° Altitude 10 AGL +/-3 ft
18.	H	Hovering turn	Heading 150° to 330° Altitude 10 AGL +/-3 ft
19.	H	High hover	Heading 330° +/- 5° Altitude 40 AGL +/-3 ft
20.	H	Hovering turn	Heading 330° to 150° Altitude 40 AGL +/-3 ft

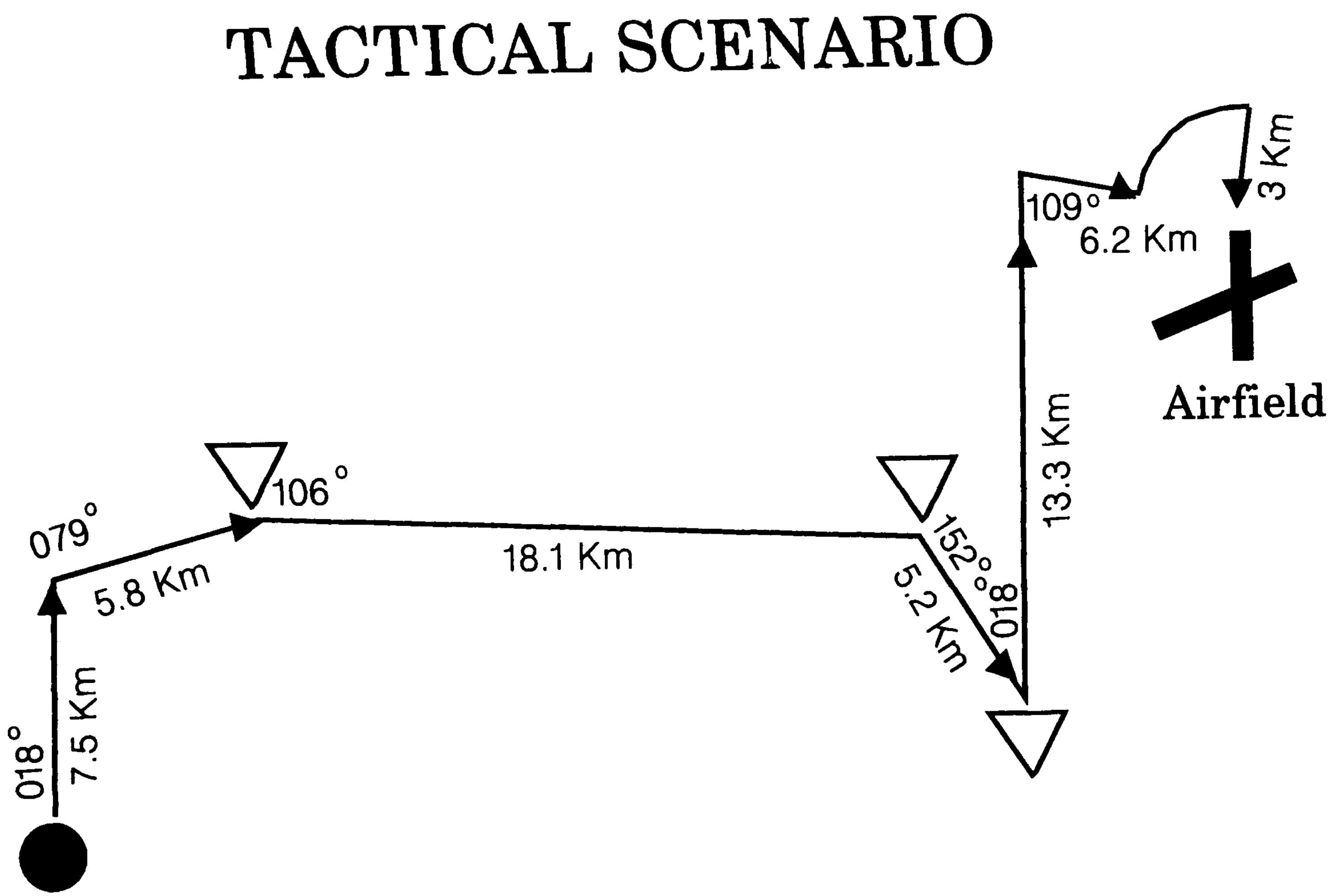

Figure D-1. Navigation flight profile.

Aircrew mission briefing
upper airwork

1. Situation

   a. Threat: Warsaw Pact motorized rifle regiment

   b. Friendly units: 1 Mech infantry company (-), 2 ADA companies (+), 1 USAF TAC fighter squadron (-).

   c. Attachments and detachments: H & C Companies (-), 4th CAB, 19th Armored Division

2. Mission

   Direct support of combat operations requiring an airborne radiological survey.

3. Execution

   a. Mission type: Airborne chemical survey

   b. Authorized conditions: VMC/IMC as required

   c. Authorized flight modes: 1,000 to 3,500' MSL

   d. Movement techniques: Tactical with appropriate coordination with supported unit.

   e. Aircraft tail number: 82-23748
      Crews: Pilot______________________________
      Copilot______________________________

   f. Special mission equipment: 2 M60Ds with 2,000 rounds of 7.62mm. AUIB CD ensemble.

   g. Authorized loads: Survey tTeam and equipment ammunition - as stated.

   h. Flight route: Takeoff at H hour local from the marshalling LZ (H), vicinity VK 85894439, heading east while climbing to 2,000 MSL and maintaining 120 KIAS. Upon leveling at 2,000 feet MSL, head 360 degrees and start the survey. The exact flight route is depicted at Figure D-2. In order to obtain useful information from the survey, times, altitudes, airspeeds and headings must be as precise as possible. Time is the most critical factor, since prolonged exposure to anticipated radiation levels may be hazardous. The flight profile has been selected to provide the maximum information and the minimum possible risk.

i. Mission restrictions: Friendly forces are engaged in and dedicated to providing total suppression of enemy air defense forces throughout the mission. USAF AWACS is dedicated to directing the TAC fighter squadron in direct support of this mission. Flight route deviation is not authorized due to the extensive enemy and friendly antiair umbrella in the area of operations (AO). Enemy use of chemical agents has been reported. Crews will be in MOPP 4 protective level throughout the operation.

j. Safety considerations: Checkpoints must be negotiated at exact times. Time schedule deviation is not authorized once the start point is crossed. Although variation of flight parameters is allowable to meet the time schedule, these variations should be kept to an absolute minimum.

4. Service support

a. Refuel/rearm location: VK 85894439

b. Ration support: Class B rations will be provided by the 4th CAB at the marshalling LZ.

c. Assembly area/bivouac. Remain overnight locations: marshalling landing area vicinity VK 85894439.

d. Maintenance support: As per 4th CAB Tactical SOP.

5. Command and signal

a. Command: (1) Air Mission Commander_______________
(2) Command or support relationship to supported unit: Direct Support (DS).

b. Signal (except for published frequencies): As per applicable CEOI and 19th AD TAC SOP.

6. Additional remarks

a. Programming and use of Doppler for this mission are mandatory.

b. Local (Cairn's AAF area) VHIRP is in effect throughout the AO.

c. Planning data:

GW: 13,850 lbs	PA: +5
Fuel: 1,925 lbs	OAT: +15
Wx: 400' OVC 1/2 M vis	Alt: 29.92

Upper airwork

Depart the confined area on a east heading while simultaneously climbing to 2000 MSL and increasing airspeed to 120 KIAS. Upon leveling at altitude, turn to a northern heading and commence the flight profile. Note: CP perform PAB (without gloves).

Mark	Time	Maneuver	Parameter
1.	Start	HAAD	Heading 360° +/- 10° Airspeed 120 knots +/- 10 Altitude 2000 MSL +/- 100 Duration 1 minute +/- 5 sec
2.	1.0	360° Left SRT	Maintain A/S & ALT Duration 2 min
3.	3.0	HAAD	Heading 360° +/- 10° Airspeed 120 knots +/- 10 Altitude 2000 MSL +/- 100 Duration 1 minute +/- 5 sec
4.	4.0	Climb 500 ft	Maintain Hdg & A/S Climb @ 500 fpm (2500) Duration 1 min
5.	5.0	180° Right SRT	Maintain A/S & ALT Duration 1 min
6.	6.0	HAD	Maintain Hdg, A/S & ALT Duration 1 min
7.	7.0	180° Right SRT	Maintain A/S & ALT Duration 1 min
8.	8.0	Climb 1000 ft	Maintain Hdg & A/S Climb @ 500 fpm (3500 MSL) Duration 2 min
9.	10.0	Descend 500 ft	Maintain Hdg & A/S Descend @ 500 fpm (3000) Duration 1 min
10.	11.0	180° Left SRT Descend 500 ft	Maintain A/S Descend @ 500 fpm (2500) Duration 1 min
11.	12.0	Descend 500 ft	Maintain Hdg & A/S Descend @ 500 fpm (2000) Duration 1 min

12.	13.0	180° Left SRT	Maintain A/S & ALT Duration 1 min
13.	13.0	HAAD	Heading 360° +/- 10° Airspeed 120 knots +/- 10 Altitude 2000 MSL +/- 100 Duration 2 min +/- 5 sec
14.	14.0	360° Right SRT	Maintain A/S & ALT Duration 2 min
15.	16.0	Descend 1000 ft	Maintain Hdg & A/S Descend @ 500 fpm (1000) Duration 2 min

Note: Pilot transfers controls to CP. CP climbs to 2000 MSL and when stable, initiates Mark 1 maneuver.

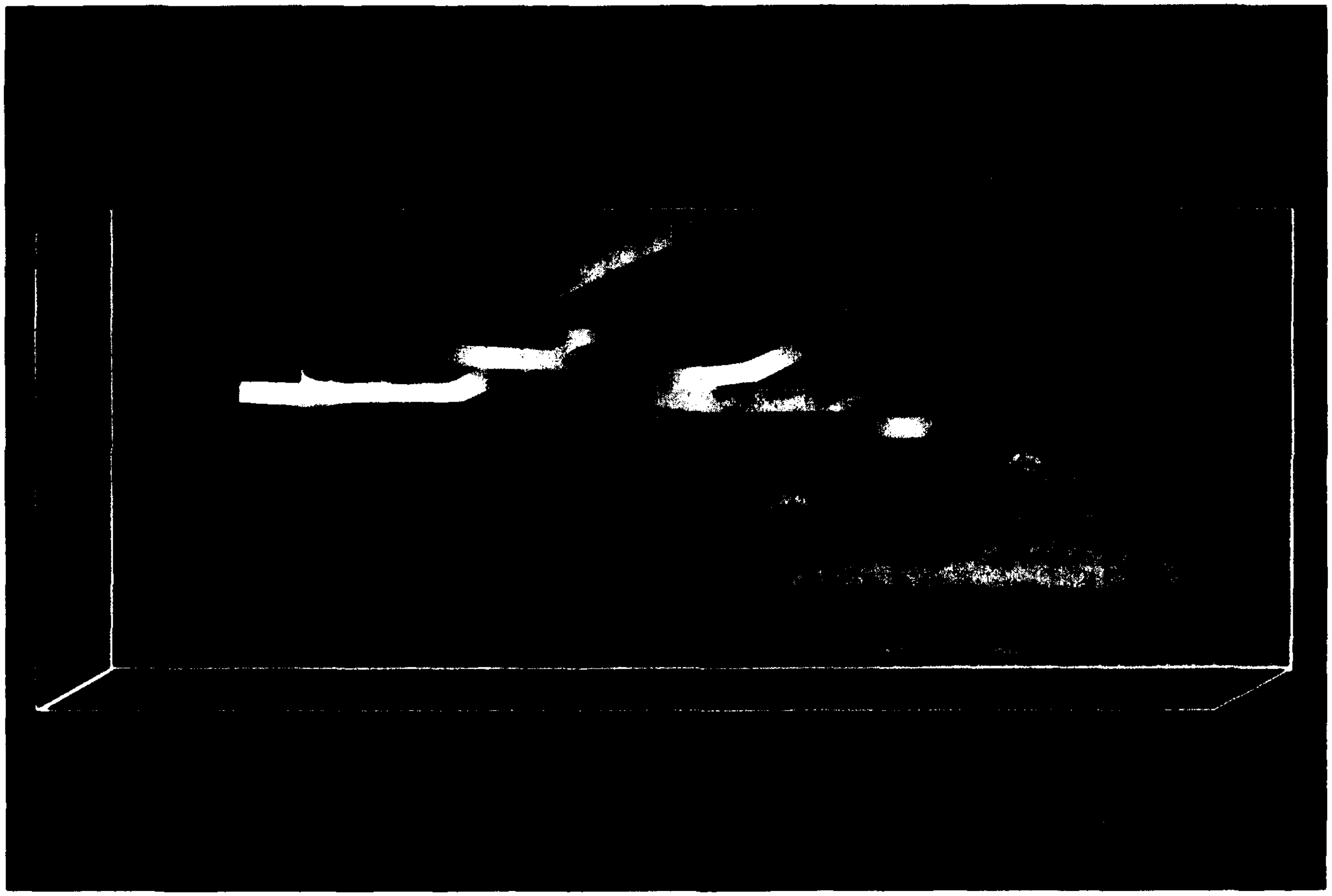

Figure D-2. Upper airwork flight profile.

<u>Appendix E.</u>

Initial subject questionnaire

INITIAL SUBJECT QUESTIONNAIRE

A. PERSONAL DATA

1. Subject ID No ____
2. Name ______________________________
3. Rank _________
4. Unit ________________________________
5. Date of birth ________MO ________DAY ________YR
6. Present marital status ______________
7. Years of Active Duty Military Service ______

B. MEDICAL HISTORY

8. How often do participate in vigorous physical exercise?

   ___Never ___Occasionally ____Regularly ____Times per wk

   Usual type of exercise ____________ _______________________

9. Average no of hours sleep per night _____
10. Have you ever smoked or chewed tobacco (regular basis?) ____

    When did you stop? _______

    Do you smoke or chew tobacco presently? ___________

    What do you smoke? _________ How much per day? _______

11. What is your present average weekly alcohol consumption? ___
12. How many cups of coffee do you normally drink per day? _____

    Caffeinated _____ Decaffeinated _____

13. How do you describe your health at present?

    _____fair _____good _____excellent

14. What if any medical problems have you had since your last flight physical? ____

15. Are you presently taking any medication, prescribed or otherwise ? _____Yes _____No

If yes, what? ____

16. Do you require corrective lenses for flying? ____Yes ____No

17. Handedness: Left ____ Right _____ Ambidextrous ____

18. Have you ever suffered a heat induced illness? _____

If yes, details ____

19. Do you suffer from any allergies? _____

If yes, details ____

C. FLIGHT EXPERIENCE HISTORY

	IP	PC	PI	TOTAL
20. Flight hours	____	____	____	_____
21. UH-60 flight hours	____	____	____	_____
22. UH-60 simulator hours	____	____	____	_____

23. How often do you suffer airsickness?

_____occasionally _____frequently _____never

24. How often do you suffer simulator sickness?

_____occasionally _____frequently _____never

25. When did you last fly in NBC protective clothing at MOPP 4?

____

26. Total flying hours in NBC protective clothing at MOPP 4

____

D. MEASUREMENTS

27. Height (cm) ________

28. Weight (kg) ________

29. AUIB size _____/_____

30. M43 size __________

31. Helmet size ________

32. Undershirt size _____

33. Underpants size _____

34. Boot size __________

34. Sock size __________

35. Overboot size ______

36. Flight glove size ___

37. NBC glove size ______

38. SARVIP size ________

39. Armor size _________

Appendix F.

Postflight questionnaire

SUBJECT ________

DATE ___________

STUDY CONDITION _________________

DAY # ____

INVESTIGATOR'S REMARKS:

AUIB UH-60 SIMULATOR STUDY

CLOTHING AND INDIVIDUAL EQUIPMENT SURVEY

END OF DAY QUESTIONNAIRE

The Behavioral Sciences Division at the U.S. Army Natick Research, Development and Engineering Center (NATICK) has devised this questionnaire to obtain your opinions concerning how the items in your flight ensemble affected your performance in this simulator study. NATICK is responsible for developing soldier clothing and equipment or the entire U.S. Army. Most of the items which you will be wearing in this study were developed by NATICK.

By completing this questionnaire, you will be giving us invaluable assistance in providing equipment that will enhance your ability to accomplish your flight duties. We will take your answers seriously, so please take this questionnaire seriously and answer each question carefully.

Please take into consideration only what you experienced today in responding to this questionnaire. If you do not understand a question, please ask for assistance before going on.

Thank you.

Questionnaire Section I. EASE OF PERFORMING FLIGHT ACTIVITIES

1. Please rate how easy or difficult it was to perform each of the listed activities today. Circle one answer for each activity.

VERY DIFFICULT	MODERATELY DIFFICULT	SLIGHTLY DIFFICULT	NEITHER DIFFICULT NOR EASY	SLIGHTLY EASY	MODERATELY EASY	VERY EASY
1	2	3	4	5	6	7

a. View areas inside the cockpit	1	2	3	4	5	6	7
b. Read gauges, displays, controls	1	2	3	4	5	6	7
c. See your co-pilot	1	2	3	4	5	6	7
d. View outside cockpit windows	1	2	3	4	5	6	7
e. Control the cyclic	1	2	3	4	5	6	7
f. Control the collective	1	2	3	4	5	6	7
g. Manipulate food pedals	1	2	3	4	5	6	7
h. Manipulate radio controls	1	2	3	4	5	6	7
i. Press Doppler keys	1	2	3	4	5	6	7
j. Manipulate other controls	1	2	3	4	5	6	7
k. Access ensemble components (e.g., closures, pockets)	1	2	3	4	5	6	7
l. Be heard by your co-pilot	1	2	3	4	5	6	7
m. Be heard by outside agencies	1	2	3	4	5	6	7
n. Hear co-pilot	1	2	3	4	5	6	7
o. Hear outside agencies	1	2	3	4	5	6	7
p. Hear important aircraft sounds	1	2	3	4	5	6	7
q. Bend forward to reach controls	1	2	3	4	5	6	7
r. Reach to the left	1	2	3	4	5	6	7
s. Reach to the right	1	2	3	4	5	6	7
t. Reach up above the head	1	2	3	4	5	6	7
u. Reach down	1	2	3	4	5	6	7
v. Sit properly	1	2	3	4	5	6	7

Questionnaire Section II. PERFORMANCE IMPAIRMENT ASSOCIATED WITH EACH ITEM IN THE FLIGHT ENSEMBLE.

II. A. SEEING INSIDE THE COCKPIT

1. Please rate the extent to which the items in our ensemble seemed to IMPAIR YOUR ABILITY TO SEE INSIDE THE COCKPIT (E.G., VIEW COCKPIT AREAS; READ GAUGES, DISPLAYS, CONTROLS; SEE CO-PILOT). Circle one answer for each item.

NOT AT ALL IMPAIR	SLIGHTLY IMPAIR	MODERATELY IMPAIR	CONSIDERABLY IMPAIR	EXTREMELY IMPAIR
0	1	2	3	4

a. SUIT	0	1	2	3	4
b. HELMET	0	1	2	3	4
c. MASK AND HOOD	0	1	2	3	4
d. GLOVES	0	1	2	3	4
e. BOOTS	0	1	2	3	4
f. SURVIVAL VEST/ARMOR	0	1	2	3	4

2. For each instance above where you gave a rating of '1' or higher, please EXPLAIN HOW THE ITEM(S) IMPAIRED SEEING INSIDE THE COCKPIT.

a. SUIT

b. HELMET

c. MASK AND HOOD

d. GLOVES

e. BOOTS

f. SURVIVAL VEST/ARMOR

II. B. MANIPULATING CYCLIC, COLLECTIVE, AND FOOT PEDALS

1. Please rate the extent to which the items in our ensemble seemed to IMPAIR YOUR ABILITY TO MANIPULATE THE CYCLIC, COLLECTIVE, AND FOOT PEDALS. Circle one answer for each item.

NOT AT ALL IMPAIR	SLIGHTLY IMPAIR	MODERATELY IMPAIR	CONSIDERABLY IMPAIR	EXTREMELY IMPAIR
0	1	2	3	4

a. SUIT	0	1	2	3	4
b. HELMET	0	1	2	3	4
c. MASK AND HOOD	0	1	2	3	4
d. GLOVES	0	1	2	3	4
e. BOOTS	0	1	2	3	4
f. SURVIVAL VEST/ARMOR	0	1	2	3	4

2. For each instance above where you gave a rating of '1' or higher, please EXPLAIN HOW THE ITEM(S) IMPAIRED MANIPULATION OF THE CYCLIC, COLLECTIVE, AND FOOT PEDALS.

a. SUIT

b. HELMET

c. MASK AND HOOD

d. GLOVES

e. BOOTS

f. SURVIVAL VEST/ARMOR

II. C. MANIPULATING OTHER CONTROLS/SWITCHES, ETC.

1. Please rate the extent to which the items in our ensemble seemed to IMPAIR YOUR ABILITY TO MANIPULATE OTHER CONTROLS/SWITCHES (E.G., RADIO, DOPPLER, THROTTLE, INTERCOM, CLOCK). Circle one answer for each item.

NOT AT ALL IMPAIR	SLIGHTLY IMPAIR	MODERATELY IMPAIR	CONSIDERABLY IMPAIR	EXTREMELY IMPAIR
0	1	2	3	4

a. SUIT	0	1	2	3	4
b. HELMET	0	1	2	3	4
c. MASK AND HOOD	0	1	2	3	4
d. GLOVES	0	1	2	3	4
e. BOOTS	0	1	2	3	4
f. SURVIVAL VEST/ARMOR	0	1	2	3	4

2. For each instance above where you gave a rating of '1' or higher, please EXPLAIN HOW THE ITEM(S) IMPAIRED MANIPULATING OTHER CONTROLS.

a. SUIT

b. HELMET

c. MASK AND HOOD

d. GLOVES

e. BOOTS

f. SURVIVAL VEST/ARMOR

II. D. MOVING THE BODY AND ARMS TO REACH CONTROLS AND OTHER OBJECTS

1. Please rate the extent to which the items in our ensemble seemed to IMPAIR YOUR ABILITY TO IMPAIR YOUR ABILITY TO MOVE YOUR BODY AND ARMS REACH CONTROLS AND OTHER OBJECTS (E.G., BENDING FORWARD; REACHING ABOVE THE HEAD, DOWN TO THE LEFT, AND TO THE RIGHT). Circle one answer fo each item.

NOT AT ALL IMPAIR	SLIGHTLY IMPAIR	MODERATELY IMPAIR	CONSIDERABLY IMPAIR	EXTREMELY IMPAIR
0	1	2	3	4

a. SUIT	0	1	2	3	4
b. HELMET	0	1	2	3	4
c. MASK AND HOOD	0	1	2	3	4
d. GLOVES	0	1	2	3	4
e. BOOTS	0	1	2	3	4
f. SURVIVAL VEST/ARMOR	0	1	2	3	4

2. For each instance above where you gave a rating of '1' or higher, please EXPLAIN HOW THE ITEM(S) IMPAIRED MOVING THE BODY AND ARMS.

a. SUIT

b. HELMET

c. MASK AND HOOD

d. GLOVES

e. BOOTS

f. SURVIVAL VEST/ARMOR

Questionnaire Section III. OTHER COMPATIBILITY ISSUES.

1. Did you experience any difficulties drinking from the canteen during today's sessions? Please put an 'X' next to your answer.

   YES _____ NO _____ DIDN'T USE CANTEEN TODAY _____

   If 'YES', please give details:

2. Did you have any problems with the seat restraint harness which were related to what you were wearing in today's sessions? Please put an 'X' next to your answer.

   YES _____ NO _____

   If 'YES', please give details:

3. Did you encounter any difficulties reading materials and handling items positioned on your lap (e.g., using kneeboard)? Please put an 'X' next to your answer.

   YES _____ NO _____

   If 'YES', please give details:

4. Did you experience problems in today's sessions that had to do with items in the flight ensemble interfering with each other? Please put an 'X' next to your answer.

   YES _____ NO _____

   If 'YES', please give details:

Questionnaire Section IV. COMFORT, FIT, AND HEAT STRESS.

1. Please rate how <u>HOT</u> you felt in today's sessions. Circle one answer for each flight.

	NOT AT ALL HOT	SLIGHTLY HOT	MODERATELY HOT	CONSIDERABLY HOT	EXTREMELY HOT
a. FIRST SORTIE	0	1	2	3	4
b. SECOND SORTIE	0	1	2	3	4
c. THIRD SORTIE	0	1	2	3	4

****

IF YOU ANSWERED <u>NOT AT ALL</u> TO <u>ALL PARTS</u> OF THE ABOVE QUESTION, SKIP THE REMAINING QUESTIONS ON THIS PAGE AND GO ON TO QUESTION 4 ON THE NEXT PAGE.

****

2. Please rate how important <u>BEING HOT</u> was in affecting your ability to accomplish your duties today. Circle one answer for each flight.

NOT AT ALL IMPORTANT	SLIGHTLY IMPORTANT	MODERATELY IMPORTANT	VERY IMPORTANT	EXTREMELY IMPORTANT
0	1	2	3	4

a. FIRST SORTIE	0	1	2	3	4
b. SECOND SORTIE	0	1	2	3	4
c. THIRD SORTIE	0	1	2	3	4

3. Please rate how important each of the items in your ensemble was in <u>MAKINC YOU FEEL HOT</u> in today's sessions. Circle one answer for each item.

NOT AT ALL IMPORTANT	SLIGHTLY IMPORTANT	MODERATELY IMPORTANT	VERY IMPORTANT	EXTREMELY IMPORTANT
0	1	2	3	4

SUIT	0	1	2	3	4
HELMET	0	1	2	3	4
MASK	0	1	2	3	4
MASK HOOD	0	1	2	3	4
FLIGHT GLOVES	0	1	2	3	4
RUBBER GLOVES	0	1	2	3	4
SURVIVAL VEST	0	1	2	3	4
ARMOR PLATE/CARRIER	0	1	2	3	4
FLIGHT BOOTS	0	1	2	3	4
OVERBOOTS	0	1	2	3	4

4. Did you experience any major problems with FIT or COMFORT of the items (OTHER THAN HEAT STRESS)? Answer by placing an 'X' next to 'YES' or 'NO' for each item listed. Where you answer 'yes', please explain what the problem was in the space provided. If the fit or comfort problem affected your performance, give details in your answer.

a. SUIT YES_____ NO_____

Please explain

b. HELMET YES_____ NO_____

Please explain

c. MASK YES_____ NO_____

Please explain

d. MASK HOOD YES_____ NO_____

Please explain

e. FLIGHT GLOVES AND RUBBER GLOVES YES_____ NO_____

Please explain

f. SURVIVAL VEST/ ARMOR PLATE/CARRIER YES_____ NO_____

Please explain

g. FLIGHT BOOTS AND OVERBOOTS YES_____ NO_____

Please explain

Questionnaire Section V. OVERALL QUESTIONS.

1. Please rate the overall acceptability of the flight ensemble for wear during missions conducted under environmental conditions like you experienced today. Circle one number.

VERY UNACCEPTABLE	MODERATELY UNACCEPTABLE	SOMEWHAT UNACCEPTABLE	NEITHER UNACCEPTABLE NOR ACCEPTABLE	SOMEWHAT ACCEPTABLE	MODERATELY ACCEPTABLE	VERY ACCEPTABLE
1	2	3	4	5	6	7

2. What was the WORST problem which you experienced IN TODAY'S SESSIONS related to wearing your ensemble? Please give details below and indicate what you think can be done to the ensemble to improve the situation:

WORST PROBLEM:

WHAT CAN BE DONE:

Appendix G.

Volunteer consent forms

VOLUNTEER AGREEMENT AFFIDAVIT

For use of this form, see AR 70-25; the proponent agency is OTSG

PRIVACY ACT OF 1974

Authority: 10 USC 3013, 44 USC 3101, and 10 USC 1071-1087.

Principle Purpose: To document voluntary participation in the Clinical Investigation and Research Program. SSN and home address will be used for identification and locating purposes.

Routine Uses: The SSN and home address will be used for identification and locating purposes. Information derived from the study will be used to document the study; implementation of medical programs; adjudication of claims; and for the mandatory reporting of medical conditions as required by law. Information may be furnished to Federal, State and local agencies.

Disclosure: The furnishing of your SSN and home address is mandatory and necessary to provide identification and to contact you if future information indicates that your health may be adversely affected. Failure to provide the information may preclude your voluntary participation in this investigational study.

PART A(1) - VOLUNTEER AFFIDAVIT

Volunteer Subjects in Approved Department of the Army Research Studies

· Volunteers under the provisions of AR 40-38 and AR 70-25 are authorized all necessary medical care for injury or disease which is the proximate result of their participation in such studies.

I, ______________________________, SSN ______________,

having full capacity to consent and having attained my ______________ birthday, do hereby volunteer/~~give consent as legal representative for~~ ______________________________, to participate in Physiological effects of wearing the Aircrew Uniform Integrated Battlefield (AUIB) while flying the UH-60 simulator in a controlled heat environment

(Research study)

under the direction of LTC Robert Thornton, M.D.

conducted at U.S. Army Aeromedical Research Laboratory.

(Name of Institution)

The implications of my voluntary participation/~~consent as legal representative~~, duration and purpose of the research study; the methods and means by which it is to be conducted; and the inconveniences and hazards that may reasonably be expected have been explained to me by

____

I have been given an opportunity to ask questions concerning this investigational study. Any such questions were answered to my full and complete satisfaction. Should any further questions arise concerning my rights/the rights of the person I represent on study-related injury, I may contact*

LTC George Sisson, Command Judge Advocate General

at HQ USAMRDC, FT Detrick, Frederick, MD Tel: (AV)343-2065 (Comm)(301)663-2065

(Name, Address and Phone Number of Hospital (Include Area Code))

I understand that I may at any time during the course of this study revoke my consent and withdraw/have the person I represent withdrawn from the study without further penalty or loss of benefits; however, I/the person I represent may be required (military volunteer) ~~or requested (civilian volunteer)~~ to undergo certain examination if, in the opinion of the attending physician, such examinations are necessary for my/the person I represent's health and well-being. My/~~the person I represent's~~ refusal to participate will involve no penalty or loss of benefits to which I am/the person I represent is otherwise entitled.

____

PART A (2) - ASSENT VOLUNTEER AFFIDAVIT *(MINOR CHILD)*

I, ______________________________, SSN ______________ having full capacity to consent and having attained my ______________ birthday, do hereby volunteer for ______________ ______________ to participate in ______________

(Research Study)

under the direction of ______________________________

conducted at ______________________________.

(Name of Institution)

(Continue on reverse)

DA FORM 5303-R, MAY 88

PREVIOUS EDITIONS ARE OBSOLETE

PART A(2) - ASSENT VOLUNTEER AFFIDAVIT (*MINOR CHILD*) (*Cont'd.*)

~~The implications of my voluntary participation; the nature, duration and purpose of the research study; the methods and means by which it is to be conducted; and the inconveniences and hazards that may reasonably be expected have been explained to me by~~

___

~~I have been given an opportunity to ask questions concerning this investigational study. Any such questions were answered to my full and complete satisfaction. Should any further questions arise concerning my rights I may contact~~

___

~~at ___~~

(Name, Address, and Phone Number of Hospital (Include Area Code))

~~I understand that I may at any time during the course of this study revoke my assent and withdraw from the study without further penalty or loss of benefits; however, I may be requested to undergo certain examination if, in the opinion of the attending physician, such examinations are necessary for my health and well-being. My refusal to participate will involve no penalty or loss of benefits to which I am otherwise entitled.~~

___

PART B - TO BE COMPLETED BY INVESTIGATOR

INSTRUCTIONS FOR ELEMENTS OF INFORMED CONSENT: *(Provide a detailed explanation in accordance with Appendix E, AR 40-38 or AR 70-25.)*

The aim of the trial is to assess the new CD uniform (the AUIB and M43 mask) in the UH-60 aeromedical simulator, in both cool and hot conditions. It will take two working weeks to complete, and you will be flying for up to 6 hours per day; alternating duties between pilot and copilot.

The USAARL UH-60 simulator is an aeromedical version of the standard training simulator, with an additional system that controls cockpit temperature and humidity. You will be flying in cool and hot conditions, both with and without NBC equipment, and can expect to log up to 60 simulator hours, depending on how long it takes you to train on the particular flight profile we have devised.

At the beginning of each day you will be instrumented to record your temperature and heart rate, both to gain experimental data, and to make sure that you do not exceed rigidly designed parameters which are written into the protocol to ensure your safety. Your core body temperature will be measured using a probe in your external ear canal mounted in an E.A.R. foam ear plug. A trained medical monitor will be with you in the simulator at all times to observe your core temperature and ensure your well-being. A flight surgeon will be on immediate standby should any problem arise. You may of course terminate the trial yourself at any stage should you develop any subjective symptoms which make you feel you cannot continue, such as excessive headache or nausea.

(Continued on next page)

I do ☐ do not ☐ *(check one & initial)* consent to the inclusion of this form in my outpatient medical treatment record.

SIGNATURE OF VOLUNTEER	DATE	SIGNATURE OF LEGAL GUARDIAN *(if volunteer is a minor)*

PERMANENT ADDRESS OF VOLUNTEER	TYPED NAME OF WITNESS	
	SIGNATURE OF WITNESS	DATE

REVERSE OF DA FORM 5303-R, MAY 88

DA FORM 5303-R, MAY 88
PART B (Continued)

The objective criteria which will be used to terminate the experiment are core temperature reaching 39.5°C, or a heart rate of 150 for more than 15 minutes.

The simulator is instrumented to enable accurate measurement of flight parameters, and will be used in conjunction with several computer-based tests to measure the effect of the AUIB and heat on your performance. Other factors affecting performance obviously can interfere with the experiment, and so we will be inviting you to ensure that you get a good night's sleep each day, and refrain from alcohol- and caffeine-containing beverages for the duration of the experiment. Your urine will be tested for alcohol and caffeine each morning.

The only other risks to you are of skin irritation due to the prolonged wearing of NBC equipment and the monitoring electrodes. If you have a history of such problems, you should make this clear to the flight surgeon at the initial briefing.

During the second week, each day will begin with a 30-minute period of light exercise on a treadmill (at a slow walk) to represent the added workload of preflighting the aircraft. You will be allowed free access to water during the flights, through the M43 drinking tube on the NBC days, but you will not be able to eat.

Records of the trial will not identify you by name nor will you be identifiable in any subsequent report. The aim is to present group data showing how large numbers of aviators perform.

Your participation in this trial is very important to the Army and to our aviation community in particular, thus we hope you will always perform your best throughout the trials. You will undoubtably learn more about yourself and your ability to perform in such conditions as we are studying, and you will be contributing to our knowledge of how best to design equipment and procedures for flying in chemical threat environments.

I have received a copy of this volunteer consent form.

VOLUNTEER REGISTRY DATA SHEET

THIS FORM IS AFFECTED BY THE PRIVACY ACT OF 1974

AUTHORITY: 5 USC 301; 10 USC 1071-1090; 44 USC 3101; EO 9397

Principal and Routine Purposes: To document participation in research conducted or sponsored by the U.S. Army Medical Research and Development Command. Personal information will be used for identification and location of participants.

Mandatory or Voluntary Disclosure: The furnishing of the SSN is mandatory and necessary to provide identification and to contact you if future information indicates that your health may be adversely affected. Failure to provide the information may preclude your participation in the research study.

PART A-INVESTIGATOR INFORMATION

(To Be Completed By Investigator)

PLEASE PRINT, USING INK OR BALLPOINT PEN

1. Study NR: ________ 2. Protocol Title: Physiological effects of wearing the Aircrew Uniform Integrated Battlefield (AUIB) while flying the UH-60 simulator in a controlled heat environment.

3. Contractor (Laboratory/Institute Conducting Study):

4. Study Period: From: 01/__/__ (DA/MO/YR) To: 15/__/__ (DA/MO/YR)

5. Principal/Other Investigator(s) Names(s) — 6. Location/Laboratory

(1) Thornton, Robert (Last) (First) (MI) — Ft Rucker/ USAARL

(2) ________ — ____/____

(3) ________ — ____/____

PART B-VOLUNTEER INFORMATION

(To Be Completed By Volunteer)

PLEASE PRINT, USING INK OR BALLPOINT PEN

7. SSN: ___/___/____ 8. Name: ________ (Last) (First) (MI)

9. Sex: M X F__ 10. Date of Birth: __/__/__ 11. *MOS/~~Job Series~~: __ 12. *Rank/~~Grade~~: __

13. Permanent Home Address (Home of Record) or Study Location Address:

________ (Street) (P.O. Box/Apartment No.)

________ (City) (Country) (State) (Zip Code)

________ (Perm Home Phone No)

14. *Local Address (If Different From Permanent Address):

________ (Street) (P.O. Box/Apartment No.)

________ (City) (Country) (State) (Zip Code)

________ (Local Phone No)

15. *Military Unit: ________ Zip Code: ________

Organization: ________ Post: ________ Duty Phone No. ________

USAMRDC Form 60-R Revised 1Apr 88 (Supersedes previous editions)

PART C-ADDITIONAL INFORMATION

(To Be Completed By Investigator)

PLEASE PRINT, USING INK OR BALLPOINT PEN

16. Location of Study:

17. Is Study Completed: Y___ N___

    Did volunteer finish participation: Y___ N___ If YES, Date finished: ___/___/___ (DA/MO/YR)

    If NO, Date withdrawn: ___/___/___ (DA/MO/YR) Reason withdrawn:

18. Did Any Serious or Unexpected Adverse Incident or Reaction Occur: Y___N___ If YES, Explain:

19. *Volunteer Followup: ______________________________

    Purpose: ______________________________

    Date: ___/___/___ (DA/MO/YR) Was contact made: Y___N___ If No action taken, explain:

20. *Hard Copy Records Retired: Place: ____________________ File NR: ____________________

21. *Product Information:

    Product: ______________________________

    Manufacturer: ______________________________

    Lot NR: ____________________ Expiration Date: __________

    NDA NR: ____________________ IND/IDE NR: __________

*Indicates that item may be left blank if information is unavailable or does not apply.
Entries must be made for all other items.

Unconditional consent for use of picture and sound

The United States Government is granted the right to use, to the extent and for the purpose it desires, any pictures (still, motion, those retransmitted via TV or recorded on video tape or otherwise) and sounds (vocal, instrumental, or otherwise) whether used together or separately, taken or recorded by or on behalf of the U.S. Army Aeromedical Research Laboratory.

____________________ ____________________________________
(DATE) (SIGNATURE)

____
(HOME ADDRESS)

____
(MILITARY ADDRESS)

Above consent obtained by: ________________________________
(SIGNATURE)

Physiological effects of wearing the Aircrew Uniform Integrated Battlefield (AUIB) while flying the UH-60 helicopter simulator in a controlled heat environment

Physicians' statement

After review of medical records and the subjects' questionnaire answers, the subject is authorized to participate in all aspects of this study.

Subject: ______________________ SSN: ______________

Signed: ________________ (Physician)

Print: ________________

Date: __________

Appendix H.

Manufacturers' list

Boisig Instruments Inc
P.O. Box 860
Champlain, NY 12919

Digital Equipment Corporation
110 Spit Brook Road
Nashua, NH 03062-2698

Lotus Development Corporation
55 Cambridge Parkway
Cambridge, MA 02142

Paravant Computer Systems
7800 Technology Drive
Melbourne, FL 32904

Reuter Stokes Canada Limited
465 Dobbie Drive
Cambridge, Ontario
Canada N1R 5X9

SAS Institute Inc.
P.O. Box 8000
Cary, NC 27512-8000

Science/Electronics
P.O. Box 986
Dayton, OH 45401

SPSS Inc.
444 North Michigan Avenue
Chicago, IL 60611

Vermont Medical Inc.
Bellows Falls, VT 05101

Yellow Springs Instrument Co.
P.O. Box 279
Yellow Springs, OH 45387

Appendix I.

Postflight questionnaire analysis

The original postflight questionnaire has been reproduced as in Appendix F, except that the numbers to circle have been replaced by the mean score from all subjects. The written comments have also been summarized, where appropriate. Numbers in parentheses refer to the number of respondents who made that comment. All information that has been added to the original questionnaire appears in bold type.

AUIB UH-60 SIMULATOR STUDY

CLOTHING AND INDIVIDUAL EQUIPMENT SURVEY

END OF DAY QUESTIONNAIRE

The Behavioral Sciences Division at the U.S. Army Natick Research, Development and Engineering Center (NATICK) has devised this questionnaire to obtain your opinions concerning how the items in your flight ensemble affected your performance in this simulator study. NATICK is responsible for developing soldier clothing and equipment or the entire U.S. Army. Most of the items which you will be wearing in this study were developed by NATICK.

By completing this questionnaire, you will be giving us invaluable assistance in providing equipment that will enhance your ability to accomplish your flight duties. We will take your answers seriously, so please take this questionnaire seriously and answer each question carefully.

Please take into consideration only what you experienced today in responding to this questionnaire. If you do not understand a question, please ask for assistance before going on.

Thank you.

Questionnaire Section I. EASE OF PERFORMING FLIGHT ACTIVITIES

1. Please rate how easy or difficult it was to perform each of the listed activities today. Circle one answer for each activity.

VERY DIFFICULT	MODERATELY DIFFICULT	SLIGHTLY DIFFICULT	NEITHER DIFFICULT NOR EASY	SLIGHTLY EASY	MODERATELY EASY	VERY EASY
1	2	3	4	5	6	7

		BASE-LINE	STD HOT	NBC COOL	NBC HOT
a.	View areas inside the cockpit	6.7	6.1	2.6	2.6
b.	Read gauges, displays, controls	6.7	6.1	2.8	2.7
c.	See your copilot	6.7	6.1	2.5	2.8
d.	View outside cockpit windows	6.7	6.1	3.0	3.2
e.	Control the cyclic	6.7	6.1	4.1	4.5
f.	Control the collective	6.7	6.1	4.1	4.6
g.	Manipulate food pedals	6.7	6.1	3.4	3.6
h.	Manipulate radio controls	6.7	6.1	2.9	3.6
i.	Press Doppler keys	6.7	6.1	2.8	3.6
j.	Manipulate other controls	6.7	6.1	3.6	3.1
k.	Access ensemble components (e.g., closures, pockets)	6.7	6.1	3.6	2.9
l.	Be heard by your copilot	6.7	6.1	5.3	5.3
m.	Be heard by outside agencies	6.7	6.1	5.3	5.3
n.	Hear copilot	6.7	6.1	5.3	5.3
o.	Hear outside agencies	6.7	6.1	5.3	5.3
p.	Hear important aircraft sounds	6.7	6.1	4.8	5.8
q.	Bend forward to reach controls	6.6	5.9	3.8	3.6
r.	Reach to the left	6.6	5.9	3.4	3.5
s.	Reach to the right	6.6	5.9	3.0	3.5
t.	Reach up above the head	6.6	5.9	3.3	3.5
u.	Reach down	6.6	4.8	3.2	3.1
v.	Sit properly	6.6	4.6	3.5	3.4

Questionnaire Section II. PERFORMANCE IMPAIRMENT ASSOCIATED WITH EACH ITEM IN THE FLIGHT ENSEMBLE.

II. A. SEEING INSIDE THE COCKPIT

1. Please rate the extent to which the items in our ensemble seemed to IMPAIR YOUR ABILITY TO SEE INSIDE THE COCKPIT E.G., VIEW COCKPIT AREAS; READ GAUGES, DISPLAYS, CONTROLS; SEE CO-PILOT). Circle one answer for each item.

NOT AT ALL IMPAIR	SLIGHTLY IMPAIR	MODERATELY IMPAIR	CONSIDERABLY IMPAIR	EXTREMELY IMPAIR
0	1	2	3	4

	BASE-LINE	**STD HOT**	**NBC COOL**	**NBC HOT**
a. SUIT	**0.0**	**0.0**	**0.0**	**0.1**
b. HELMET	**0.0**	**0.0**	**0.1**	**0.1**
c. MASK AND HOOD	**0.0**	**0.0**	**2.8**	**2.4**
d. GLOVES	**0.0**	**0.0**	**0.0**	**0.1**
e. BOOTS	**0.1**	**0.0**	**0.0**	**0.1**
f. SURVIVAL VEST/ARMOR	**0.0**	**0.0**	**1.5**	**2.0**

2. For each instance above where you gave a rating of '1' or higher, please EXPLAIN HOW THE ITEM(S) IMPAIRED SEEING INSIDE THE COCKPIT.

   a. SUIT

   b. HELMET

   c. MASK AND HOOD

      Head turning limited (6) **Restricted neck flexion (6)**
      Eye pieces too small (2) **Limited peripheral vision (3)**

   d. GLOVES

      Reduced manual dexterity (1)

   e. BOOTS

      Bulky (2) **Difficulty feeling pedals (2)**

   f. SURVIVAL VEST/ARMOR

      Hose/armor interaction (13)

II. B. MANIPULATING CYCLIC, COLLECTIVE, AND FOOT PEDALS

1. Please rate the extent to which the items in our ensemble seemed to IMPAIR YOUR ABILITY TO MANIPULATE THE CYCLIC, COLLECTIVE, AND FOOT PEDALS. Circle one answer for each item.

NOT AT ALL IMPAIR	SLIGHTLY IMPAIR	MODERATELY IMPAIR	CONSIDERABLY IMPAIR	EXTREMELY IMPAIR
0	1	2	3	4

	BASE-LINE	STD HOT	NBC COOL	NBC HOT
a. SUIT	0.0	0.0	0.1	0.1
b. HELMET	0.0	0.0	0.1	0.0
c. MASK AND HOOD	0.0	0.0	0.1	0.0
d. GLOVES	0.0	0.0	0.6	0.6
e. BOOTS	0.0	0.0	0.8	1.4
f. SURVIVAL VEST/ARMOR	0.1	0.0	0.1	0.1

2. For each instance above where you gave a rating of '1' or higher, please EXPLAIN HOW THE ITEM(S) IMPAIRED MANIPULATION OF THE CYCLIC, COLLECTIVE, AND FOOT PEDALS.

a. SUIT

Restrictive (1)   Bulky (1)

b. HELMET

c. MASK AND HOOD

d. GLOVES

Dexterity (4)

e. BOOTS

Difficult to feel pedal microswitches (9)   Bulky (1)

f. SURVIVAL VEST/ARMOR

Restrictive (1)

II. C. MANIPULATING OTHER CONTROLS/SWITCHES, ETC.

1. Please rate the extent to which the items in our ensemble seemed to IMPAIR YOUR ABILITY TO MANIPULATE OTHER CONTROLS/SWITCHES (E.G., RADIO, DOPPLER, THROTTLE, INTERCOM, CLOCK). Circle one answer for each item.

NOT AT ALL IMPAIR	SLIGHTLY IMPAIR	MODERATELY IMPAIR	CONSIDERABLY IMPAIR	EXTREMELY IMPAIR
0	1	2	3	4

	BASE-LINE	STD HOT	NBC COOL	NBC HOT
a. SUIT	0.0	0.0	0.0	0.1
b. HELMET	0.0	0.0	0.0	0.0
c. MASK AND HOOD	0.0	0.0	0.9	1.4
d. GLOVES	0.1	0.1	1.2	1.8
e. BOOTS	0.0	0.0	0.0	0.3
f. SURVIVAL VEST/ARMOR	0.0	0.0	0.3	0.4

2. For each instance above where you gave a rating of '1' or higher, please EXPLAIN HOW THE ITEM(S) IMPAIRED MANIPULATING OTHER CONTROLS.

a. SUIT

b. HELMET

c. MASK AND HOOD

Neck flexion restricted (7)
Difficulty seeing switches (4)

d. GLOVES

Dexterity (11)   Bulk (2)

e. BOOTS

f. SURVIVAL VEST/ARMOR

Mask hose/SARVIP interaction (3)

II. D. MOVING THE BODY AND ARMS TO REACH CONTROLS AND OTHER OBJECTS

1. Please rate the extent to which the items in our ensemble seemed to IMPAIR YOUR ABILITY TO IMPAIR YOUR ABILITY TO MOVE YOUR BODY AND ARMS TO REACH CONTROLS AND OTHER OBJECTS (E.G., BENDING FORWARD; REACHING ABOVE THE HEAD, DOWN TO THE LEFT, AND TO THE RIGHT). Circle one answer for each item.

NOT AT ALL IMPAIR	SLIGHTLY IMPAIR	MODERATELY IMPAIR	CONSIDERABLY IMPAIR	EXTREMELY IMPAIR
0	1	2	3	4

	BASE-LINE	STD HOT	NBC COOL	NBC HOT
a. SUIT	0.0	0.0	0.1	0.4
b. HELMET	0.0	0.0	0.0	0.0
c. MASK AND HOOD	0.0	0.0	0.8	1.0
d. GLOVES	0.0	0.0	0.0	0.0
e. BOOTS	0.0	0.0	0.0	0.0
f. SURVIVAL VEST/ARMOR	0.2	0.3	0.8	0.9

2. For each instance above where you gave a rating of '1' or higher, please EXPLAIN HOW THE ITEM(S) IMPAIRED MOVING THE BODY AND ARMS.

a. SUIT

b. HELMET

c. MASK AND HOOD

Mask hose/SARVIP interaction (9)
Head movement restricted (2)

d. GLOVES

e. BOOTS

f. SURVIVAL VEST/ARMOR

Difficult to move around (5) **Impaired seat movement (4)**

Questionnaire Section III. OTHER COMPATIBILITY ISSUES.

1. Did you experience any difficulties drinking from the canteen during today's sessions? Please put an 'X' next to your answer.

   YES _____ NO _____ DIDN'T USE CANTEEN TODAY _____

   If 'YES', please give details:

   Difficulty using drinking tube (3)

2. Did you have any problems with the seat restraint harness which were related to what you were wearing in today's sessions? Please put an 'X' next to your answer.

   YES _____ NO _____

   If 'YES', please give details:

   Hard to buckle (4)

3. Did you encounter any difficulties reading materials and handling items positioned on your lap (e.g., using kneeboard)? Please put an 'X' next to your answer.

   YES _____ NO _____

   If 'YES', please give details:

   Limited neck flexion (6)

4. Did you experience problems in today's sessions that had to do with items in the flight ensemble interfering with each other? Please put an 'X' next to your answer.

   YES _____ NO _____

   If 'YES', please give details:

   Mask hose/SARVIP interaction (10)

Questionnaire Section IV. COMFORT, FIT, AND HEAT STRESS.

1. Please rate how HOT you felt in today's sessions. Circle one answer for each flight.

NOT AT ALL HOT	SLIGHTLY HOT	MODERATELY HOT	CONSIDERABLY HOT	EXTREMELY HOT
0	1	2	3	4

	BASE-LINE	STD HOT	NBC COOL	NBC HOT
a. FIRST SORTIE	0.0	1.6	0.4	2.3
b. SECOND SORTIE	0.0	1.6	0.4	3.1
c. THIRD SORTIE	0.0	1.6	0.4	3.6

****

IF YOU ANSWERED NOT AT ALL TO ALL PARTS OF THE ABOVE QUESTION, SKIP THE REMAINING QUESTIONS ON THIS PAGE AND GO ON TO QUESTION 4 ON THE NEXT PAGE.

****

2. Please rate how important BEING HOT was in affecting your ability to accomplish your duties today. Circle one answer for each flight.

NOT AT ALL IMPORTANT	SLIGHTLY IMPORTANT	MODERATELY IMPORTANT	VERY IMPORTANT	EXTREMELY IMPORTANT
0	1	2	3	4

	BASE-LINE	STD HOT	NBC COOL	NBC HOT
a. FIRST SORTIE	0.0	0.8	0.1	1.7
b. SECOND SORTIE	0.0	1.1	0.1	2.4
c. THIRD SORTIE	0.0	1.1	0.1	3.5

3. Please rate how important each of the items in your ensemble was in MAKING YOU FEEL HOT in today's sessions. Circle one answer for each item.

NOT AT ALL IMPORTANT	SLIGHTLY IMPORTANT	MODERATELY IMPORTANT	VERY IMPORTANT	EXTREMELY IMPORTANT
0	1	2	3	4

	BASE-LINE	**STD HOT**	**NBC COOL**	**NBC HOT**
SUIT	**0.0**	**0.4**	**0.7**	**2.8**
HELMET	**0.1**	**0.9**	**0.3**	**2.0**
MASK AND HOOD			**1.1**	**3.0**
FLIGHT GLOVES	**0.0**	**0.3**		
RUBBER GLOVES			**0.9**	**2.2**
ARMOR PLATE/CARRIER	**0.0**	**0.4**	**0.9**	**1.4**
FLIGHT BOOTS	**0.0**	**0.3**		
OVERBOOTS			**0.6**	**2.3**

4. Did you experience any major problems with FIT or COMFORT of the items (OTHER THAN HEAT STRESS)? Answer by placing an 'X' next to 'YES' or 'NO' for each item listed. Where you answer 'yes', please explain what the problem was in the space provided. If the fit or comfort problem affected your performance, give details in your answer.

a. SUIT YES_____ NO_____

Please explain

b. HELMET YES_____ NO_____

Please explain **Hot spots (2)**

c. MASK YES_____ NO_____

Please explain **Skin irritation (2)**

d. MASK HOOD YES_____ NO_____

Please explain **Harness hot spots (5)**

e. FLIGHT GLOVES AND RUBBER GLOVES YES_____ NO_____

Please explain **Rubber gloves uncomfortable (2)**

f. SURVIVAL VEST/ ARMOR PLATE/CARRIER YES_____ NO_____

Please explain **Too heavy (3)**

g. FLIGHT BOOTS AND OVERBOOTS YES_____ NO_____

Please explain **Rub on shins (1)**

Questionnaire Section V. OVERALL QUESTIONS.

1. Please rate the overall acceptability of the flight ensemble for wear during missions conducted under environmental conditions like you experienced today. Circle one number.

VERY UNACCEPTABLE	MODERATELY UNACCEPTABLE	SOMEWHAT UNACCEPTABLE	NEITHER UNACCEPTABLE NOR ACCEPTABLE	SOMEWHAT ACCEPTABLE	MODERATELY ACCEPTABLE	VERY ACCEPTABLE
1	2	3	4	5	6	7

BASE-LINE	**STD HOT**	**NBC COOL**	**NBC HOT**
6.5	**5.8**	**4.1**	**3.5**

2. What was the WORST problem which you experienced IN TODAY'S SESSIONS related to wearing your ensemble? Please give details below and indicate what you think can be done to the ensemble to improve the situation:

WORST PROBLEM:

Mask hose/SARVIP interaction (8)
Field of view (5)
Sweat in eyes (2)

WHAT CAN BE DONE:

Microclimate cooling (5)
Move mask hose attachment (4)
Increase size of mask viewing area (4)

Appendix J.

Abbreviations

Abbreviations

AGL	Above ground level
ACP	Air check points
AFCS	Automatic flight control system
AMPM	Aircrew member's protective mask
ANOVA	Analysis of variance
AO	Area of operations
AUIB	Aircrew Uniform Integrated Battlefield
BPM	Beats per minute
CRT	Cathode ray tube
DA	Doppler/altitude
DIG	Digital image generator
DS	Direct support
ECS	Environmental control system
GLM	General linear models
I/O	Instructor/operator
IPE	Individual protective equipment
NBC	Nuclear biological chemical
NDF	Number degrees from [course]
NRDEC	Natick Research Development and Engineering Center
PAB	Performance assessment battery
P^2NBC^2	Physiological and psychological effects of the NBC environment and sustained operations in combat
PTFE	Polytetrafluoroethylene
RH	Relative humidity
RMS	Root mean square
RAD	Radar Altitude Display
SARVIP	Survival armor recovery vest (including packets)
USAARL	United States Army Aeromedical Research Laboratory
WBGT	Wet bulb globe temperature

Initial distribution

Commander, U.S. Army Natick Research,
Development and Evaluation Center
ATTN: STRNC-MIL (Documents Librarian)
Natick, MA 01760-5040

U.S. Army Communications-Electronics Command
ATTN: AMSEL-RD-ESA-D
Fort Monmouth, NJ 07703

Commander/Director
U.S. Army Combat Surveillance and Target Acquisition Lab
ATTN: DELCS-D
Fort Monmouth, NJ 07703-5304

Commander
10th Medical Laboratory
ATTN: Audiologist
APO New York 09180

Naval Air Development Center
Technical Information Division
Technical Support Detachment
Warminster, PA 18974

Commanding Officer, Naval Medical Research and Development Command
National Naval Medical Center
Bethesda, MD 20814-5044

Deputy Director, Defense Research and Engineering
ATTN: Military Assistant for Medical and Life Sciences
Washington, DC 20301-3080

Commander, U.S. Army Research Institute of Environmental Medicine
Natick, MA 01760

U.S. Army Avionics Research and Development Activity
ATTN: SAVAA-P-TP
Fort Monmouth, NJ 07703-5401

Library
Naval Submarine Medical Research
Box 900, Naval Sub Base
Groton, CT 06349-5900

Director, U.S. Army Human Engineering Laboratory
ATTN: Technical Library
Aberdeen Proving Ground, MD 210

Commander
Man-Machine Integration System
Code 602
Naval Air Development Center
Warminster, PA 18974

Commander
Naval Air Development Center
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