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Simulator Sickness in the CH-47 (Chinook) Flight Simulator

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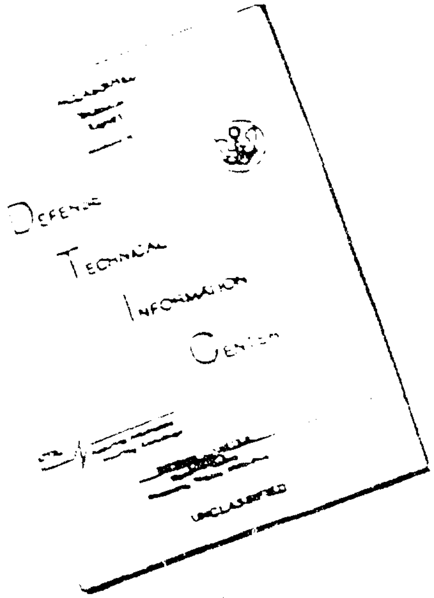

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Introduction

U.S. Army's involvement with simulator sickness

Prior to the actual fielding of the AH-64 Apache combat mission simulator (CMS) at U.S. Army installations, training of Apache pilots was conducted at the Singer Link facility in Binghamton, New York. Anecdotal information indicated some of the pilots and instructor operators (IO) were experiencing symptoms of simulator sickness resembling those reported in U.S. Navy and U.S. Coast Guard systems. Some students took Dramamine™ to alleviate their symptoms. In May 1986, documentation of the problem reached the U.S. Army Aeromedical Research Laboratory (USAARL) at Fort Rucker, Alabama. In July 1986, the Aviation Training Brigade at Fort Rucker formed a study group to examine the Apache training program. One of the issues studied was simulator sickness.

A survey of existing training records and a literature search were conducted by USAARL in August 1986. Training records of 115 students from the CMS showed that 7 percent of the students had sufficient symptoms to warrant a comment on their grade slips. The literature search led USAARL investigators to visit the Naval Training Systems Center (NTSC) in Orlando, Florida. From that association has grown a working relationship geared to capitalize on lessons learned from past research and expand the database of simulator sickness studies. As part of that search, it also was discovered that a U.S. Army flight surgeon had conducted an independent survey of the incidence of simulator sickness in the AH-1 Cobra flight weapons simulator (FWS) located in Germany (Crowley, 1987).

In the report to the Army study group, it was recommended a problem definition study be conducted to ascertain more accurately the scope and nature of the problem of simulator sickness in the Apache CMS. The request for that study was received from the Directorate of Training and Doctrine, Fort Rucker, Alabama, in February 1987. The protocol for the study was approved by the USAARL Scientific Review Committee on 4 May 1987. USAARL Report No. 88-1 documents the results of that first study.

As reported in Baltzley et al. (1989), 25 percent of those reporting aftereffects indicated their symptoms persisted longer than 4 hours while 8 percent lasted 6 hours or longer. The Army data presented in that report was contaminated with effects experienced by Apache pilots who had previous experience with the Cobra FWS. Problems with other Army simulator systems also have been documented since the first study. Most notable, aviators training in the new AH-1 Cobra simulator were complaining of postsimulator exposure aftereffects which outlasted the training period by several hours. The need for further studies was apparent.

In September 1988, USAARL received a request from the Directorate of Training and Doctrine at the U.S. Army Aviation Center at Fort Rucker requesting further field studies to assess the incidence of simulator sickness in the remaining visually-coupled flight simulators. The protocol was approved 19 October 1988 and collection of data began in January 1989. This report documents the results of the data collected at the CH-47 simulator site at Fort Campbell, Kentucky.

The nature of simulator sickness

Simulator sickness is considered to be a form of motion sickness. Motion sickness is a general term for the constellation of symptoms which result from exposure to motion or certain aspects of a moving environment (Casali, 1986), although changing visual motions (Crampton and Young, 1953; Teixeira and Lackner, 1979) may induce the malady. Pathognomonic signs are vomiting and retching; overt signs are pallor, sweating, and salivation; symptoms are drowsiness and nausea (Kennedy and Frank, 1986). Postural changes occur during and after exposure. Other signs (Colehour and Graybiel, 1966; McClure and Fregly, 1972; Money, 1970; Stern et al., 1987) include changes in cardiovascular, respiratory, gastrointestinal, biomedical, and temperature regulation functions. Other symptoms include general discomfort, apathy, dejection, headache, stomach awareness, disorientation, lack of appetite, desire for fresh air, weakness, fatigue, confusion, and incapacitation. Other behavioral manifestations influencing operational efficiency include carelessness and incoordination, particularly in manual control. Differences between the symptoms of simulator sickness and more common forms of motion sickness are that in simulator sickness visual symptoms tend to predominate and vomiting is rare.

Advancing engineering technologies permit a range of capabilities to simulate the real world through very compelling kinematics and computer-generated visual scenes. Aviators demand realistic simulators. However, this synthetic environment can, on occasion, be so compelling that conflict is established between visual and vestibular information specifying orientation (Kennedy, 1975; Oman, 1980; Reason and Brand, 1975). It has been hypothesized that in simulators, this discrepancy occasions discomfort, or "simulator sickness" as it has been labeled, and the cue conflict theory has been offered as a working model for the phenomenon (Kennedy, Berbaum, and Frank, 1984). In brief, the model postulates the referencing of motion information signaled by the retina, vestibular apparatus, or sources of somatosensory information to "expected" values based on a neural store which reflects past experience. A conflict between expected and experienced flight dynamics of sufficient magnitude can exceed a pilot's ability to adapt, inducing in some cases simulator sickness.

The U.S. Navy conducted a survey of simulator sickness in 10 flight trainers where motion sickness experience questionnaires and performance tests were administered to pilots before and after some 1200 separate exposures (Kennedy et al., 1987b). From these measures on pilots, several findings emerged: (a) Specific histories of motion sickness were predictive of simulator sickness symptomatology; (b) postural equilibrium was degraded after flights in some simulators; (c) self-reports of motion sickness symptomatology revealed three major symptom clusters: Gastrointestinal, visual, and vestibular; (d) certain pilot experiences in simulators and aircraft were related to severity of symptoms experienced; (e) simulator sickness incidence varied from 10 to 60 percent; (f) substantial perceptual adaptation occurs over a series of flights; and (g) there was almost no vomiting or retching, but some severe nausea and drowsiness.

Another recent study suggests that inertial energy spectra in moving base simulators may contribute to simulator sickness (Allgood et al., 1987). The results showed the incidence of sickness was greater in a simulator with energy spectra in the region described as nauseogenic by the 1981 Military Standard 1472C (MIL-STD-1472C) and high sickness rates were experienced as a function of time exceeding these very low frequency (VLF) limits. Therefore, the U.S. Navy has recommended, for any moving-base simulator which is reported to have high incidences of sickness, frequency times acceleration recordings of pilot/simulator interactions should be made and compared with VLF guidelines from MIL-STD-1472C. However, in those cases where illness has occurred in a fixed-base simulator, other explanations and fixes are being sought.

Of particular concern in the area of safety are simulator induced posteffects. Gower et al. (1987) showed that as symptoms decreased over flights for pilots training in the AH-64 CMS, suggesting that pilots were adapting to the discordant cues in the simulator, postflight ataxia increased suggesting that pilots were having to readapt to the normal environment. Such readaptation phenomena parallel findings from other motion environments including long-term exposure onboard ships (Fregly and Graybiel, 1965), centrifuges (Fregly and Kennedy, 1965) and space flight (Homick and Reschke, 1977). For example, Graybiel and Lackner (1983) found 54 percent of the posteffects of parabolic flight lasted longer than 6 hours and 14 percent lasted 12 hours or more. In their report, the primary symptoms reported were dizziness and postural disequilibrium. The similarity of symptomatology between these experiences leads us to believe simulator sickness poses safety of flight issues which cannot be ignored.

Materials

Description of the aircraft system

The CH-47 is a twin-turbine-engine tandem rotor helicopter designed for transportation of cargo, troops, and weapons during day, night, visual, and instrument conditions (TM 55-1520-240-10) (Figures 1 and 2). The helicopter, manufactured by Boeing-Vertol, can carry cargo internally and transport low-density aerodynamic or high-density loads suspended beneath it on slings. Powered by two T55-L-712 shaft turbine engines, the two tandem three-bladed rotor systems are capable of lifting nearly 20,000 pounds of cargo or troops. The aircraft's maximum gross weight is 50,000 pounds. The rotor systems are counterrotating, fully articulated fiberglass blades driven by the engines through engine transmissions, a combining transmission, then through drive shafts to reduction transmissions. The forward rotor system and its transmission are located on a pylon above the cockpit. The aft rotor system and transmission are located in the aft cabin section and pylon section. Drive shafts connect the forward and aft transmissions with the combining transmission through tunnels along the top of the aircraft. An auxiliary power unit (APU) provides electrical power and hydraulic pressure for ground operations when the main engines and rotor are not working.

The aircraft is equipped with four nonretractable landing gears. The wheels allow for ground taxi and maneuver. The forward gears are fixed cantilever type and each has two wheels. The rear gears each have a single wheel which can be swiveled 360 degrees or power locked to the centered position. The aft right landing gear is controlled by a control knob located in the cockpit for added maneuverability. This system is hydraulically operated and electrically controlled by the power steering control system.

There are two entrances to the aircraft. The aft loading ramp, which is hydraulically powered, is used for loading cargo and troops. The entrance door on the right side is used for personnel access to the cargo and cockpit area. The entrance door on the side of the cargo area is a two-part door allowing for the upper part to lift and swing out of the way into the ceiling area. The lower part of the door forms the stairway when it is opened. Additionally, there are two jettisonable doors with sliding upper section windows in the cockpit area for the pilot's exit. These are not used on a routine basis.

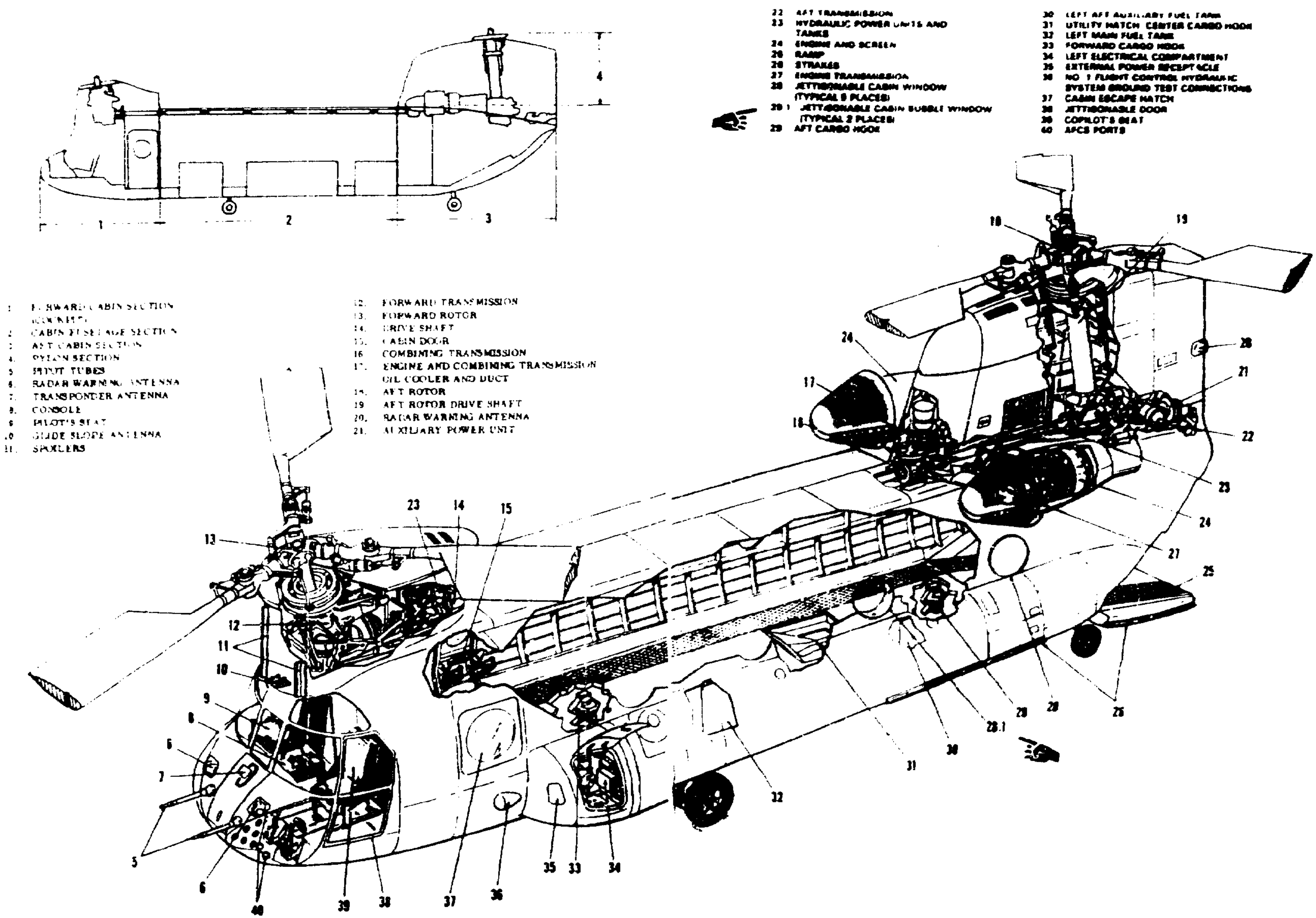

Figure 1. General arrangement.

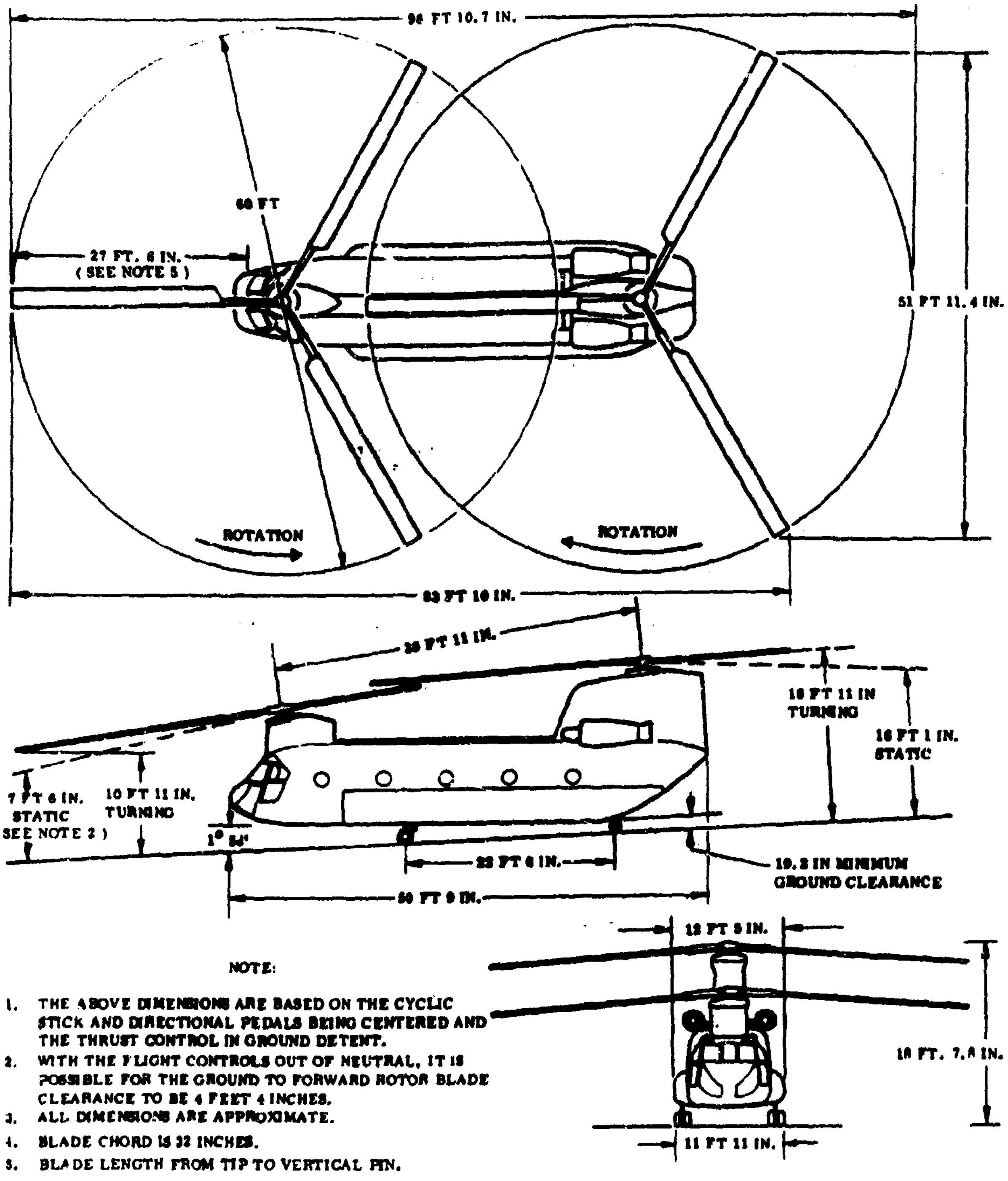

Figure 2. Principal dimensions diagram.

Fuel is stored in six tanks mounted along the sides of the fuselage. They are capable of holding approximately 1,000 gallons of JP-4 fuel and supplying the engines, heater, and the APU.

Unlike most helicopters which require antitorque action in the form of a tail rotor, the CH-47 uses counter-rotating rotor systems to effect lift and thrust for flight. Therefore, the actions of the pilot's controls in the cockpit effect the same maneuver as in other rotorcraft, but through different actions in the linkages and rotor systems. For instance, in a normal rotorcraft, directional control is accomplished through the pedals by increasing and decreasing the pitch in the tail rotor system. This is accomplished through the pedals as well, in the CH-47; however, the pedals impart equal and opposite lateral cyclic pitch to the blades during the maneuver.

The CH-47 has an advanced flight control system (AFCS) which stabilizes the helicopter about all axes and enhances control response. The system is capable of automatically maintaining desired airspeed, altitude, bank angle, and heading. Two methods of holding altitude are used, one for barometric pressure and one using the radar altimeter. The radar altimeter is used in sling load operations or other times when the mission calls for hovering for extended time periods. Unique to this system is that control inputs from the AFCS are not readily apparent to the pilot. This is because the AFCS inputs commands to the rotor systems through the integrated lower control actuators (ILCAS) which move the upper flight controls, but not the cockpit controls.

Armament consists of the M24 or M41 armament subsystems. The M24 subsystem consists of two M60D 7.62 mm machine guns (Figure 3). They are mounted one on each side of the aircraft in the cabin door and the cabin escape hatch. The machine guns are free pointing at the command of the operator, but are limited in traverse, elevation, and depression by the use of cam surfaces, stops on the pintles, and pintle posts. The M60D machine gun is a link belt fed, gas operated, air cooled automatic weapon (Figure 4). Each is fed from an ammunition can on the left side, and spent rounds are collected in an ejection bag mounted on the right side. The M41 subsystem is similar to the M24 with the exception it is located and mounted on the ramp of the aircraft.

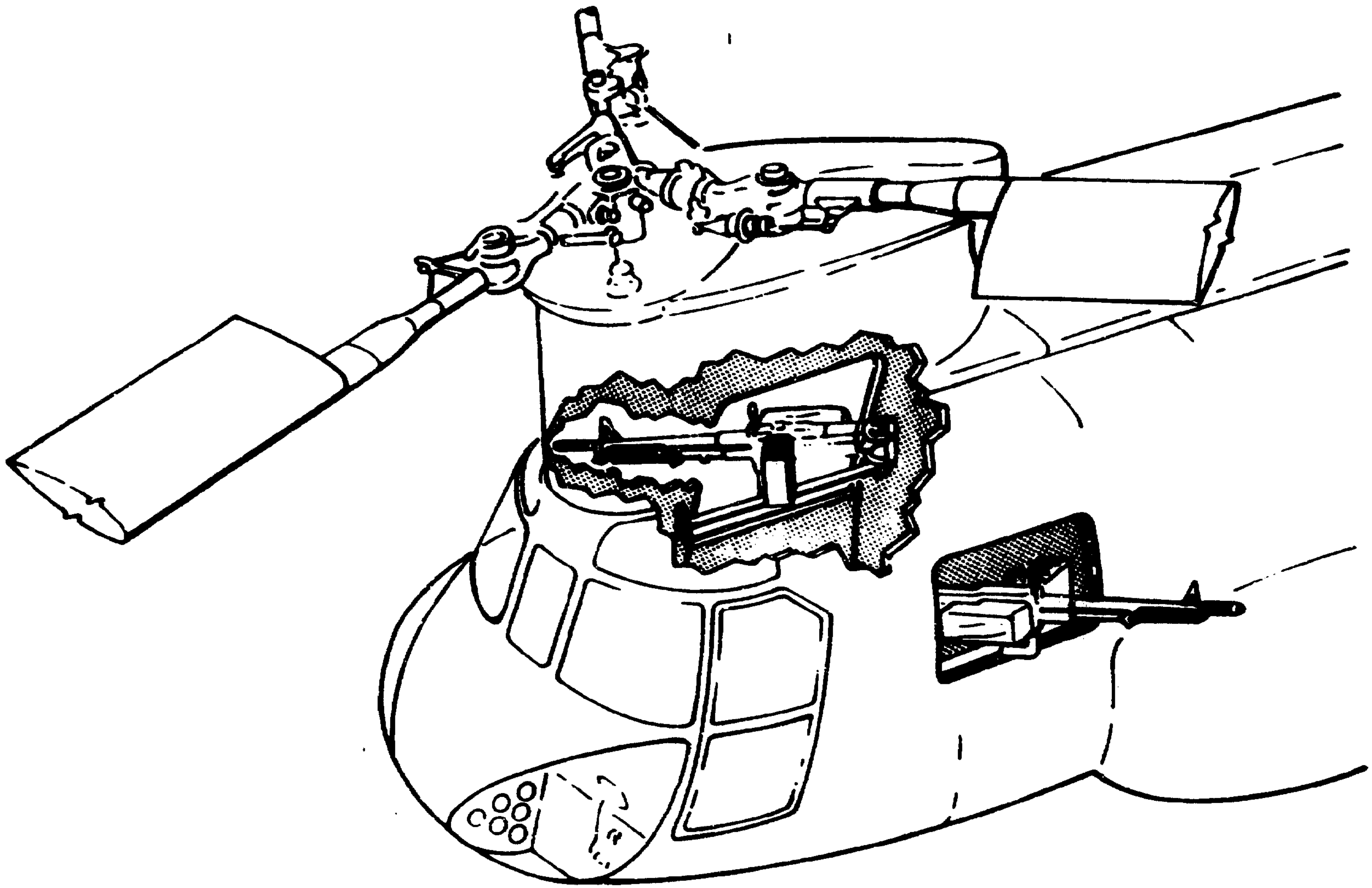

Figure 3. M24 armament subsystem.

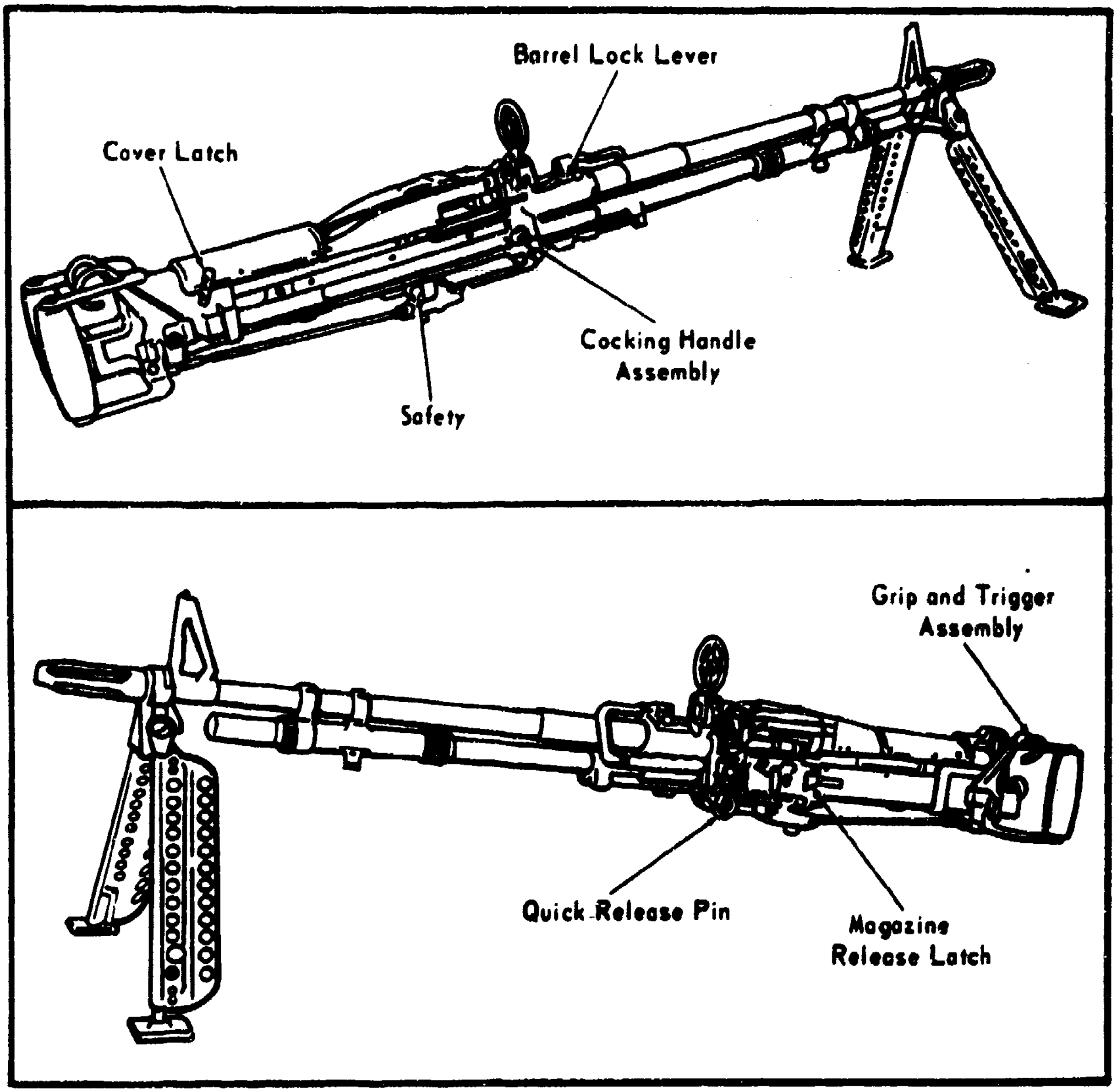

Figure 4. Machine gun (M60D).

Description of the simulator system

The CH-47D flight simulator (Model 2B31) is a motion-based simulator for training pilots in the use of the CH-47D (Chinook) helicopter (TM 55-6930-212-10). The simulator operation involves capabilities such as engine performance, flying qualities, aircraft systems performance and operation, radio communications and navigational systems performance and operation, environmental effects, and flightpath. The simulator can be used to provide transition and continuation training in all normal run-up and shutdown procedures as well as normal and emergency flight maneuvers and navigation. A list of training tasks is shown in Table 1.

The device, mounted on a six-degree-of-freedom hydraulic motion system, is controlled by a central computer. The instructor-trainee station houses a cockpit station in the forward position and an instructor operator station (IOS) (Figure 5). The station is provided with a visual system, motion, and a sound simulation system.

The trainee station houses an exact replica of the actual aircraft cockpit. This includes pilots' seats, instrument panels, flight controls, and cockpit windows. All controls and instruments are simulated and are actual aircraft parts. The ambient temperature of the simulator compartment is controlled by a thermostat located on the right wall of the compartment. However, the cockpit environmental control system switches and controls are nonfunctional.

Aural cues are provided to the pilots through a loud speaker system which is controlled by the instructor operator. This system simulates engine and transmission, rotor, APU, generators, ground start sounds, and hydraulic pump sounds through analog generation.

The motion system simulates continuous and periodic oscillations and vibrations that normally are experienced by the crewmembers during actual flight. Malfunctions which result in vibrations also are simulated. Vibrations are imparted through the seats in the cockpit area by means of an electrohydraulic seat shaker. However, these systems are isolated from the rest of the compartment by means of damping elements in the seat mountings.

Table 1.

Training tasks

Basic aircraft maneuvers	Emergency maneuvers
Cockpit procedures	Forced landings
Start-up and taxiing	Hydraulic malfunctions
Hovering flight	Fuel system malfunctions
Traffic pattern	Electrical system malfunctions
Normal takeoff from hover or the ground	AFCS malfunctions
VMC approach to hover or the ground	Engine beep trim malfunctions
Straight-and-level flight	Engine malfunctions
Level turns	Engine fire
Straight climbs and descents	Transmission malfunctions
Turning climbs and descents	
Advanced maneuvers	**Instrument maneuvers**
Maximum performance takeoff	ADF and VOR orientation, interception, and tracking
AFCS-off flight	Enroute navigation
Running landing	Holding
Autorotation	ADF, GCA, VOR, and ILS approaches
Confined-area operations	Missed approaches
Pinnacle operations	Two-way communication failure
Sling load operations	
Formation flight	
NVG operations	
Low-level, contour, and NOE flight	
Threat detection and avoidance	
Doppler navigation	

Note: ADF - Automatic direction finder
VOR - Very-high frequency omnidirectional range
GCA - Ground controlled approach
ILS - Instrument landing system
VMC - Visual meteorological conditions

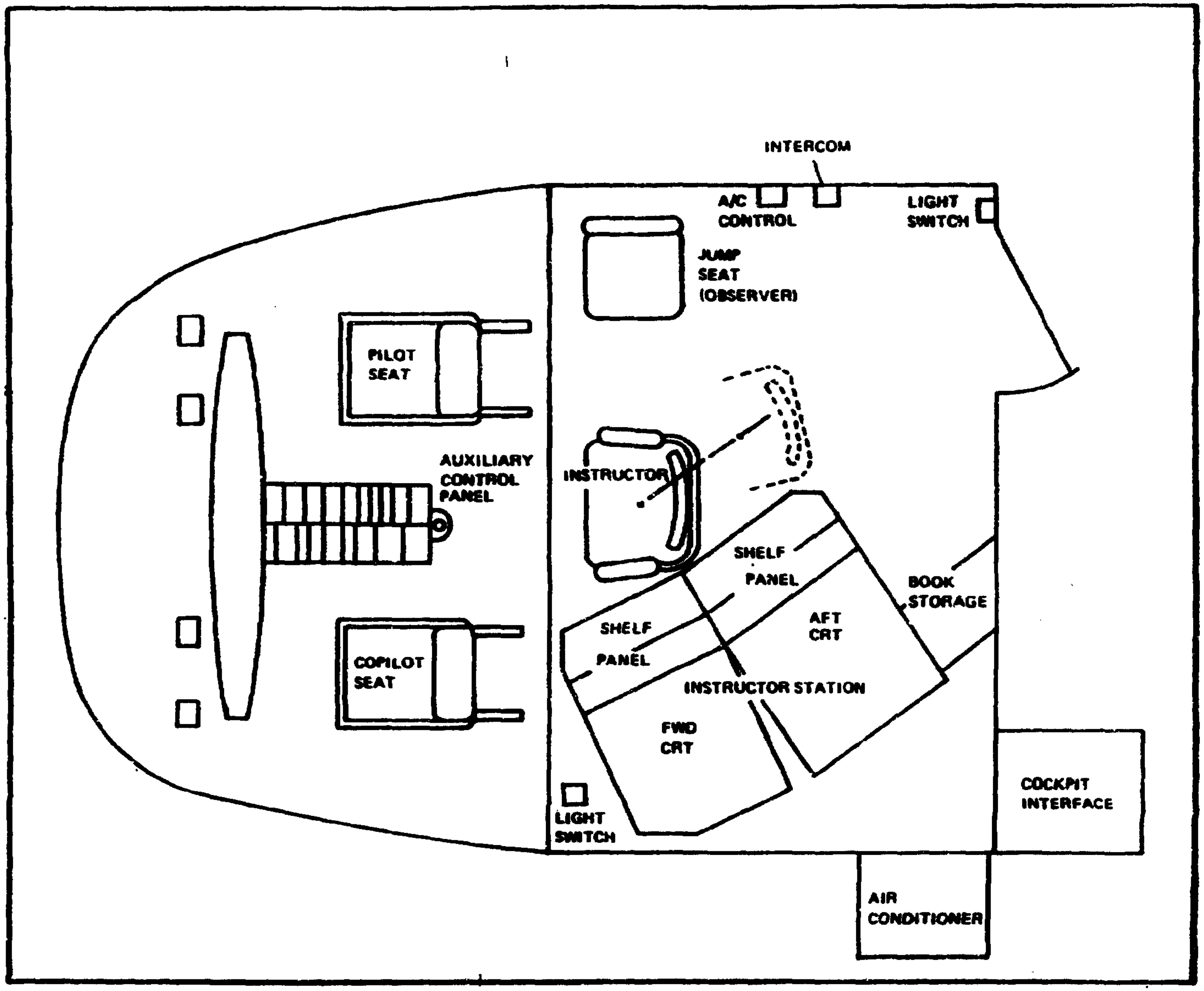

Figure 5. Flight compartment layout.

The motion system consists of a moving platform assembly that is driven and supported from below by six hydraulic actuators. This allows the system to simulate cues for pitch, roll, and yaw, as well as those vertical, lateral, and longitudinal movements which simulate various flight profiles. Motion is used to simulate changes in aircraft attitude from not only control inputs but also from rough air and wind, changes in weight and balance due to fuel consumption or cargo loading and troop displacement, or from ammunition depletion. The movements that result from blade imbalance, out-of-track conditions, and touch-down, and crash impacts also are accomplished through the motion system.

The computer system causes the motion platform to move in the appropriate direction and speed within the mechanical limits of the system. However, when acceleration cues have reached zero, the motion platform is "washed out" to zero or neutral position to prepare for the next motion input. This is true for all motions except pitch.

During ground operations, the system simulates motion with a random low frequency, low amplitude, multidirectional oscillation. This includes simulating rough terrain, effects of braking action, and lateral effects of asymmetrical braking. Transition to flight is indicated by abrupt cessation of the random oscillation and the appropriate indications of takeoff and attitude changes. During landing, the appropriate longitudinal and vertical vibrations occur as well as the landing impact as computed from the attitude and vertical and sideslip velocities. When the pilot lands too hard, a bounce is simulated. When one gear touches down too soon, the appropriate rolling and pitching effects are produced.

During flight, the system simulates the complex and repeated cues which normally occur, such as turbulence that causes changes in yaw and roll. Those vibrations which are up to 5 cycles per second that result from rotors, etc., are produced by the motion system. Above that level, the seat shaker is used to impart those vibrations to the pilots. Sling load oscillations are reproduced by the motion system.

The instructor operator station is located in the simulator compartment, adjacent to the rear of the cockpit area. The instructor operator uses the IOS to monitor and control the training session.

The simulator consists of the main computational system which is made up of three central processing units and their associated auxiliary processing units. The digital image generator system is a full-color visual display that provides imagery for day, dusk, and night scenes. There are four out-the-window (OTW) displays (two front and two side). Also, there are chin window displays that present brown and green checkerboard patterns to simulate ground patterns, and shades of grey when the aircraft is over a runway, or black and white when over a sling load. The chin windows are not realistic visual cues. The windows become a solid color when the aircraft reaches 200 feet above the ground or when it enters instrument conditions.

The visual system is compatible with night vision devices. The database provides tactical and instrument gaming areas of approximately 2,280 square kilometers. The gaming area is designed for a generic terrain useful for training cargo helicopter operations.

The fields of view (FOV) for the windows are as follows:

Window	Pilot	Copilot
Front/side		
Up	13.3	13.3
Down	22.7	22.7
Right	24	24
Left	24	24
Chin		
Horizontal	22	22
Vertical	30	30
Centered	43 down, 27.5 outboard (both)	

All measurements are in degrees with a tolerance of ± 0.5 degrees.

There are several special capabilities of the simulator system as listed in the -10 operator's manual. These are:

a. It can freeze simulator action on command.

b. Training can be initiated from any 1 of 10 predefined locations in the gaming area.

c. The simulator can be reset to an initialization point.

d. Crash override can be used to prevent an impending crash.

e. The flight can be recorded dynamically and played back (5 minutes).

f. Up to 10 simultaneous malfunctions can be presented to the trainee.

g. Prerecorded maneuvers can be flown as a demonstration.

h. The simulator can monitor program progress and trainee performance.

i. It can freeze flight parameters selectively.

j. Audio briefings can be administered by the system.

k. Emergencies will stop and abort a program.

l. Stored performance data can be printed on the printer/plotter.

m. Time history plots of airspeed, altitude, and ground track can be printed to the CRT or printer/plotter.

n. The IO can be alerted for trainee performance error.

o. Environmental conditions can be changed in flight.

p. Ground controlled approach (GCA) commands can be computed and displayed.

q. The IO can function as the flight engineer during load maneuvers.

The visual system is similar in theory and operation to that of the three other Army visually-coupled flight simulators. For additional information on that system, the reader is directed to TD 55-6930-212-23-3, Organizational and intermediate maintenance manual for the CH-47D flight simulator visual system.

Method

This field study was designed to assess incidence of simulator sickness in visually-coupled Army flight simulators. The survey measures were chosen to be comparable to those utilized in U.S. Navy and U.S. Coast Guard surveys. This way, data obtained would complement and expand the Navy's database of 10 simulators (Kennedy et al., 1987b, Van Hoy et al., 1987), the Coast Guard data (Ungs, 1987), and previous Army research conducted in the Apache Combat Mission Simulator (Gower et al., 1987). As employed in previous surveys, this study consisted of an onsite survey of pilots and IOs using a motion history questionnaire (MHQ), a motion sickness questionnaire (MSQ), and a postural equilibrium test (PET) (Appendix A).

Aviators

The 57 Army aviators surveyed ranged in age from 22 to 50 (mean 32.7, SD 8.04). Their ranks ranged from warrant officer 2 (WO2) to chief warrant officer 4 (CW4) and first lieutenant (1LT) to lieutenant colonel (LTC). Rotary-wing flight experience was in the range of 450 to 7000 flight hours (mean 2176.19). Simulator flight hours was in the range of 20 to 600 (mean 193.02).

Measures

The MHQ, originally developed by Kennedy and Graybiel (1965), is a self-report form designed to evaluate the subject's past experience with different modes of motion and the subject's reported history of susceptibility to motion sickness. The MHQ was administered once and was scored according to procedures described in Lenel, Berbaum, and Kennedy (1987).

The MSQ is designed to assess the symptomatology experienced as a result of training in the simulator. The MSQ is divided into four sections. The first section obtains preflight background information to place subjects in the proper category according to flight position, duties, total flight time in the aircraft and in the simulator, and history of recent flight time in both the aircraft and the simulator.

The second section is the preflight physiological status section. This section is administered at the simulator site, and gathers benchmark data as to the subject's recent exposure to prescription medications, illness, use of alcohol and/or tobacco products, and amount of sleep the previous night.

The third section is the simulator sickness questionnaire (SSQ) (Lane and Kennedy, 1988). The SSQ is a self-report form consisting of 28 symptoms that are rated by the participant as either being present or absent, or in terms of degree of severity on a 4-point Likert-type scale. A diagnostic scoring technique is applied to the checklist resulting in scores on three subscales--nausea, visuomotor, and disorientation, in addition to a total severity score. Scores on the nausea (N) subscale are based on the report of symptoms which relate to gastrointestinal distress such as nausea, stomach awareness, salivation, and burping. Scores on the visuomotor (V) subscale reflect the report of eyestrain-related symptoms such as eyestrain, difficulty focusing, blurred vision, and headache, while those on the disorientation (D) subscale are related to vestibular disturbances such as dizziness and vertigo. Scores on the total severity (TS) scale are an indication of overall discomfort. For all scales, a score of 100 indicates absence of sickness. The average scores for all simulators in the NTSC data base are 107.7, 110.6, 106.4, and 109.8 on the N, V, D, and TS scales, respectively.

The SSQ is administered prior to the flight and then immediately after the simulator flight, and provides data regarding any increase or decrease in severity of the symptoms the subject is experiencing. If the subject was experiencing an increase in any of the symptoms, an attempt was made to conduct a structured interview with him in order to provide some information regarding recovery from the experienced symptoms. A new question added to the postflight SSQ asked the pilots about the symptoms experienced in the simulator and whether or not they were the same as or worse than the same symptoms experienced in the aircraft conducting the same maneuvers.

The fourth section is the postflight information section which provides data on the flight conditions the pilot experienced while in the simulator and information concerning the status of the various systems within the simulator.

Postural equilibrium tests (Thomley, Kennedy, and Bittner, 1986) were administered concurrently with the MHQ and MSQ. These tests consist of three subtests, each designed to measure an aspect of postural equilibrium, as follows:

a. Walk-on-floor-with-eyes-closed (WOFEC). The subject is instructed to walk 12 heel-to-toe steps with his eyes closed and arms folded across his chest. The subject is given a score (0-12) based on the number of steps he is able to complete without sidestepping or falling. The subject is tested five times, both pre- and postflight. Subjects are scored on the average number of steps taken using the best three of the five tests.

b. Standing-on-preferred-leg-with-eyes-closed (SOPLEC). The subject designates his preferred leg (the leg he would use to kick a football) and this is annotated on the form. The subject then is asked to stand on his preferred leg for 30 seconds with his eyes closed and arms folded across his chest. The experimenter records the number of seconds the subject is able to stand without losing balance or tilting to greater than a 5 degree list from the vertical. The subject is scored on the number of seconds he is able to stand. The test is administered five times with the best three of the five being used for analysis.

c. Standing-on-nonpreferred-leg-with-eyes-closed (SONLEC). The SONLEC is administered and scored in the same manner as the SOPLEC. The SONLEC will use the opposite leg from the SOPLEC and is administered five times. The subject's score is the average number of seconds he is able to stand, using the best three of the five tests for the analysis.

Procedure

In order to gather the most comprehensive data in the least intrusive manner, the surveys were administered to all aviators who presented themselves at the simulator site for flight periods. No attempt was made to randomize the population, but rather to study the problem in the operational setting in which it is found and using flight scenarios normally found during training.

A target sample size of 100 was the objective. However, the principal training simulator at Fort Rucker, Alabama, was scheduled to undergo an upgrade at the same time the study was to be conducted. Fort Hood, Texas, was considered but could only provide a total sample size of approximately 30 aviators due to the low density of CH-47 pilots assigned there. Therefore, the site used was Fort Campbell, Kentucky. Virtually all CH-47 pilots assigned to Fort Campbell and present for duty were seen during the 2-week study. Seventy-nine observations from 57 pilots were taken. Inasmuch as they all were qualified CH-47 pilots, no qualification training was conducted. They performed currency and refresher training as prescribed by their unit instructor pilot, their particular desires or needs for training, or as prescribed by their unit training program. The investigator did not perform any intervention or exercise any control over the flights in the conduct of this survey. All aviators scheduled for flight were surveyed. Each was guaranteed anonymity and each was permitted nonparticipation. Data obtained from the questionnaires and the PET were entered into a generic database using the programs in use at the NTSC, and data reduction and analyses were performed as in previous studies. The data in this report now are incorporated into the Navy's simulator sickness database, which also includes Coast Guard data in order to determine commonality of symptoms and simulator usage and design (Gower et al., 1987).

Results

Symptomatology

Table 2 shows the number of pilots reporting key postflight symptomatology. To counter the possible inflationary effects of preflight symptomatology reported on postflight symptomatology, percentages for each particular symptom are based only on the pilots who did not report the symptom prior to training. This procedure is likely to underestimate the severity of the problem in that pilots who reported a symptom prior to the flight that was worse after the flight are not included. Symptoms have been categorized into those traditionally associated with motion sickness versus those which are associated with asthenopia (eyestrain).

Eyestrain was the most commonly reported asthenopic symptom, followed by headache. An eyestrain component is present to some degree in other forms of motion sickness (Lane and Kennedy, 1988), but is a prominent facet of simulator sickness implicating visual and visual-vestibular interactions as causal mechanisms. Improper calibration of virtual image displays may lead to excessive accommodation and vergence demands (i.e., beyond optical infinity), unequal accommodative demands between the two eyes, and conflicts between accommodation and vergence systems (Ebenholtz, 1988), all of which may produce asthenopia. It should be noted that symptoms associated with asthenopia per se include vertigo, indigestion, nausea and vomiting (Ebenholtz, 1988) and, thus, may be similar to motion sickness in terms of cause (Morrissey and Bittner, 1986).

Fatigue and sweating were the most commonly reported symptoms associated with motion sickness, followed by reports of nausea and stomach awareness. This is consistent with previous surveys of simulator sickness (Gower et al., 1987; Kennedy et al., 1987b).

In Table 3, the information in Table 2 has been presented along with comparable data available for other helicopter simulators. Incidences of symptoms shown in the table for the CH-47 simulator are comparable to the Army's AH-64 simulator and are well below those seen in the 2F64C (SH-3H simulator), the Navy's simulator associated with the highest incidence of simulator sickness.

Table 2.

Percentage* (frequencies) of aircrews reporting postflight symptomatology in the CH-47 simulator. (79 total possible cases)

Asthenopia	Percentage	Motion sickness	Percentage
Eyestrain	29.0 (22/76)	Fatigue	33.9 (21/62)
Blurred vision	5.1 (4/78)	Sweating	10.7 (8/75)
Difficulty focusing	13.0 (10/77)	Nausea	9.1 (7/77)
Difficulty concentrating	2.7 (2/74)	Dizziness (eyes closed)	3.8 (3/78)
Headache	16.7 (12/72)	Dizziness (eyes open)	0.0
		Vertigo	0.0
		Salivation increase	2.6 (2/78)
		Stomach awareness	9.1 (7/77)
		Fullness of the head	2.6 (2/76)

* Percentages for each symptom are based on aircrew who did not report the symptom prior to training.

Table 3.

Percentage* of aircrews reporting key symptomatology in seven helicopter simulators

	Army		Navy				
Simulator:	2B31	2B40	2B42	SH3H	CH46E	CH53D	CH53E
Aircraft:	CH-47	AH-64	TH-57C	2F64C	2F117	2F121	2F120
Asthenopia							
Eyestrain	29	24	27	37	16	21	23
Difficulty focus	13	6	7	24	6	6	10
Headache	17	14	7	31	12	9	17
Motion Sickness							
Nausea	9	6	5	15	9	8	11
Dizzy-eyes open	0	1	4	9	3	1	6
Stomach awareness	9	5	1	14	7	2	4
Vertigo	0	1	3	10	3	1	4
Observations:	79	434	111	223	281	159	230

* Data sources--Army 2B40: Gower et al., 1987; Navy 2B42: Fowlkes et al., 1989; Navy 2F64C, 2F117, 2F121, and 2F120: Kennedy et al., 1987b.

The SSQ scoring technique (Lane and Kennedy, 1988) was applied to the pre- and postflight symptom checklist. Descriptive statistics and values for paired measures t-tests for these data are shown in Table 4. These data show that aviators who train in the CH-47 simulator experience a statistically reliable increase in symptomatology over the course of a training session.

Figures 6 through 9 show the severity of postflight SSQ scores on each subscale along with data available for other flight simulators (both fixed- and rotary-wing). Following Lane and Kennedy's (1988) suggestion for examining postflight data, only pilots who reported they were in their usual state of fitness were included in the calculation of postflight SSQ scores presented in Figures 6 through 9. It can be seen that the severity of postflight symptomatology for the CH-47 simulator is about average for the sample on each of the SSQ scales. Lane and Kennedy (1988) suggest if means fall within the range of the upper three-to-four simulators, closer examination of the simulator is warranted. Simulator sickness in the CH-47 simulator is not severe enough to meet this criterion. However, as with other forms of motion sickness, there are marked individual differences in susceptibility to simulator sickness; 18 percent (14/78) of the aircrew training in this simulator obtained SSQ scores high enough (>118) to warrant restrictions or caution on post exposure activities.

Table 4.

Pre- and post-SSQ means (standard deviation) and values for paired t-tests. (78 observations)

Scale	Pre	Post	Difference Mean	t	p
Nausea	102.8 (6.7)	106.5 (11.9)	3.67	2.84	.006
Visuomotor	104.4 (8.5)	111.4 (13.6)	7.00	4.99	.000
Disorientation	100.7 (3.1)	105.0 (10.5)	4.28	3.65	.000
Total severity	103.5 (6.6)	109.5 (12.8)	6.04	4.52	.000

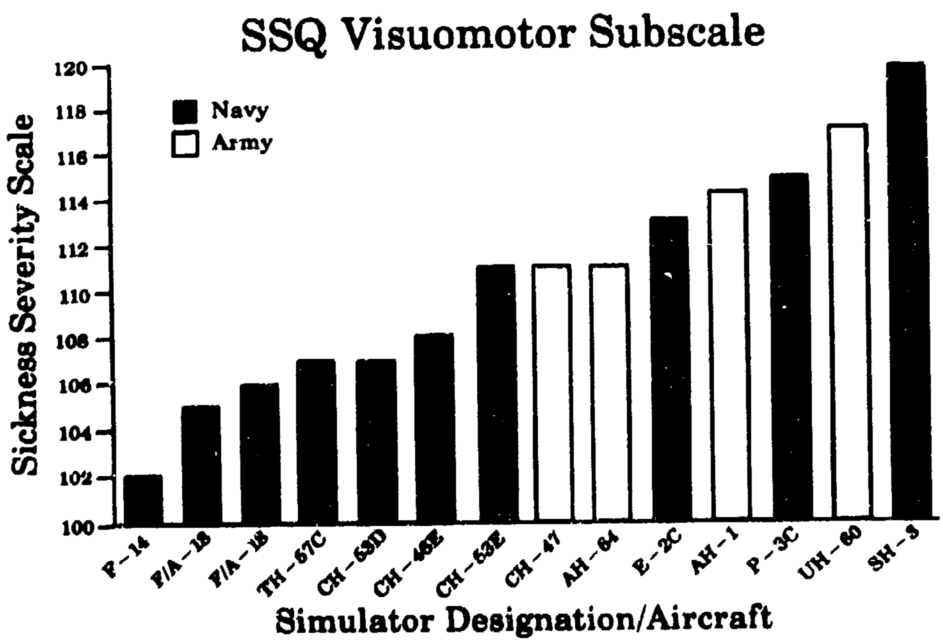

Figure 6. SSQ visuomotor subscale.

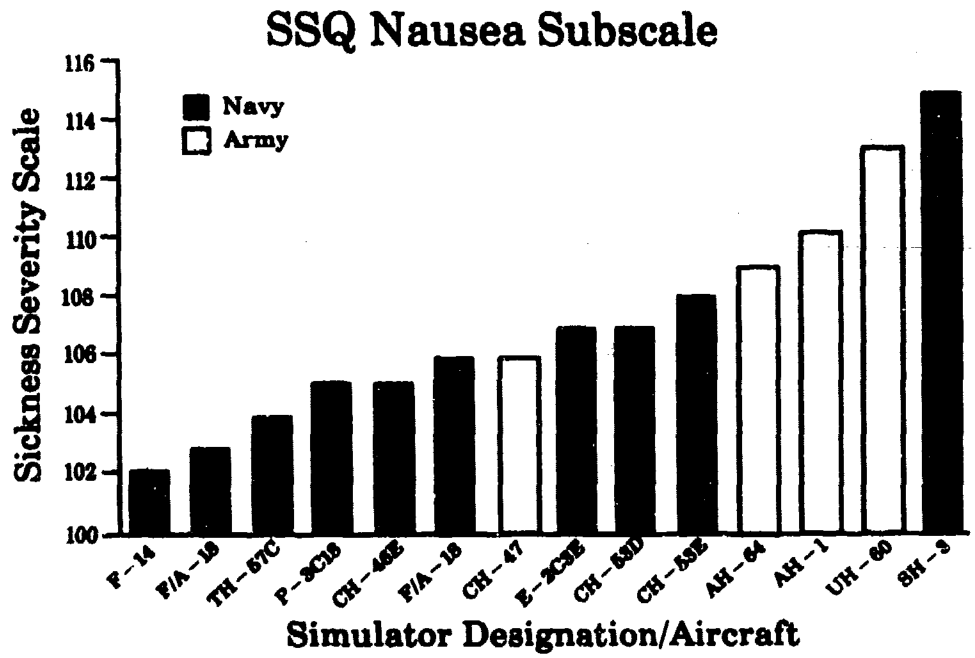

Figure 7. SSQ nausea subscale.

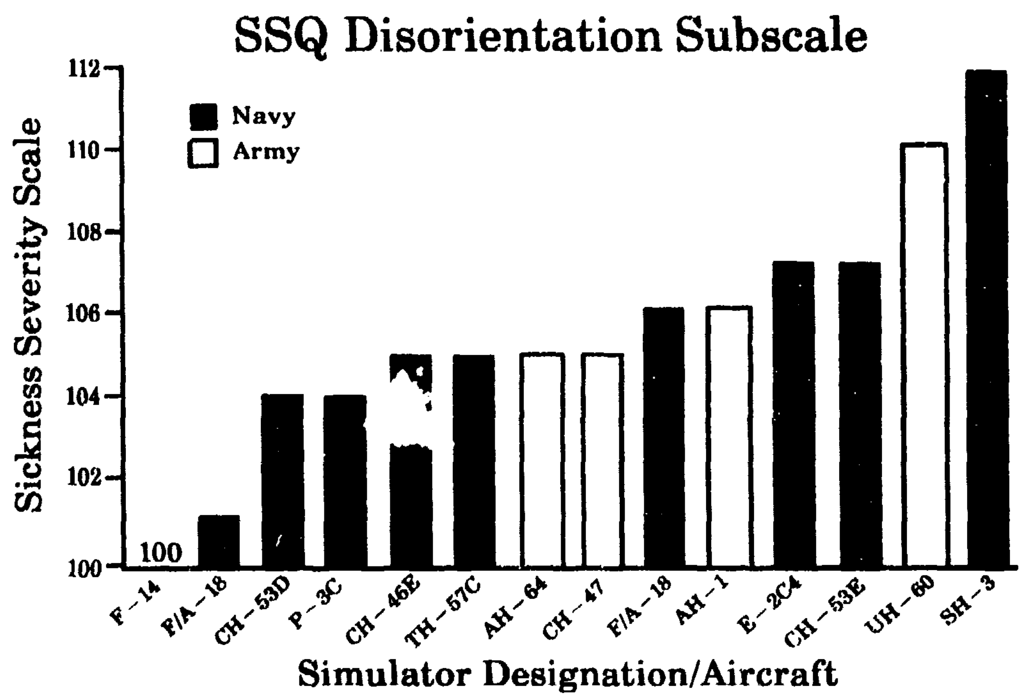

Figure 8. SSQ disorientation subscale.

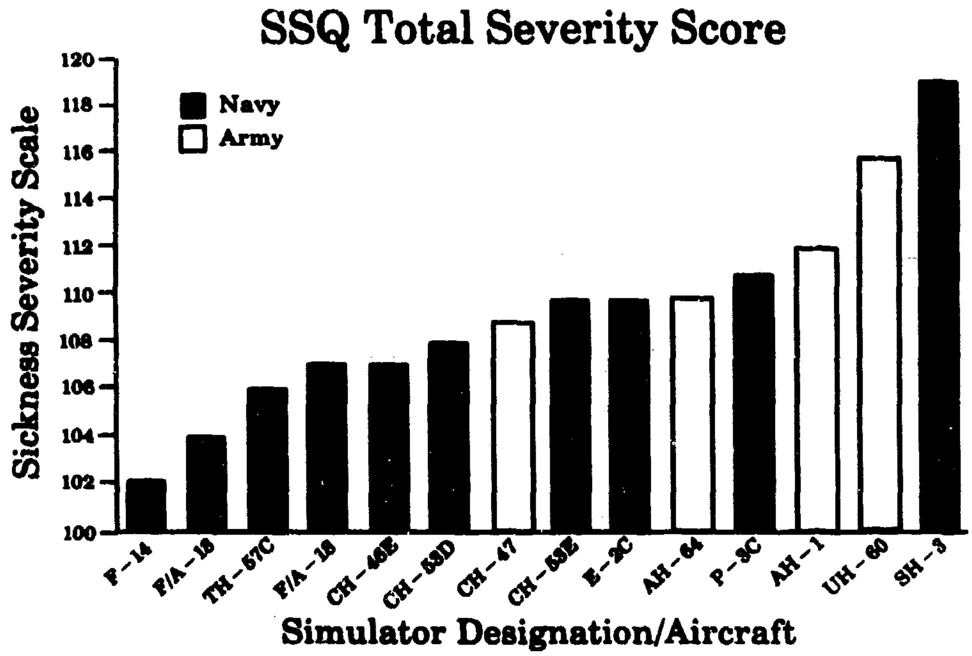

Figure 9. SSQ total severity score.

Postural stability

PET means and standard deviations, minimum and maximum scores, along with the results of paired measures t-tests are reported in Table 5. There were no reliable changes on any of the PET tests. These results, interpreted along with the mild symptomatology scores, suggest that pilots training in the CH-47 simulator are at low risk for postural disturbances postflight.

Correlations

Table 6 shows correlations for pilot, simulator, and training variables with SSQ scores. Correlations were run against all variables which (1) could rationally be expected to be related to the criterion scores, and (2) were represented by adequate frequency distributions. Descriptions and coding of these variables appear as Appendix B. Only correlations that reached the .05 level of statistical significance were presented in the table.

Table 5.

Means, standard deviations, minimum/maximum scores, values for t-tests, and observations for pre- and post-WOFLEC, SONLEC, and SOPLEC measures

	WOFEC		SONLEC		SOPLEC	
	Pre	Post	Pre	Post	Pre	Post
Mean	11.09	11.44	22.95	22.67	21.59	21.04
SD	1.73	1.33	7.60	8.04	8.58	8.51
Min-Max	5.0-12	6.3-12	5.3-30	3.3-30	3.6-30	4.6-30
t(df), p value	t(64)= -1.83	p=.07	t(64)=.38	p=.702	t(64)= .64	p=.526
Observations	65	65	65	65	65	65

Table 6.

Intercorrelations among variables (79 total possible observations)

	SSQ Scores			
Pilot variables	N	V	D	TS
Simulator hours	-.28		-.26	-.26
Enough sleep		.25		
Simulator sickness	.25	.23	.27	.28
Simulator variables				
Systems on/off	-.23		-.31	-.23
Collective		.26		
Pitch		.31		.25
Torque		.20		
Percent NOE	.37	.31	.29	.36
Freeze	.29	.21	.28	.28
Training variables				
Different from aircraft	.50	.41	.43	.50
Discomfort hampers training	.43	.26	.29	.36

Pilot variables

Reduced symptoms were associated with greater simulator hours suggesting that adaptation to nauseogenic simulator cues reduces symptomatology. Pilots' ratings of whether they got enough sleep were related to symptomatology, suggesting that this may be an easily obtained and useful predictor variable. In addition, whether simulator sickness occurred in the past was predictive of SSQ scores. Also, it was noted that correlations between MHQ and sickness scores failed to reach statistical significance. Most likely, this was due to the low SSQ scores seen in this simulator and consequent range restriction in the data.

Simulator variables

Aircrews who indicated there were systems turned off that were needed for the flight were more likely to experience simulator sickness. Variables related to aircraft control ("collective, pitch, roll, and torque") showed the worse the aircrew rated the controls, the more severe the symptomatology. These correlations suggest, as the simulation becomes more unlike the actual aircraft, the symptomatology increases. Throughput delays and visual-motion lags in the simulator itself could be sources contributing to symptomatology.

Greater percentage of nap-of-the-earth (NOE) flying was associated with increased simulator sickness. While the majority of aircrews survey in this study (80 percent) did not conduct NOE flight, for those who did, NOE flying appeared to be provocative. The greater number of times the simulator was put on freeze, the greater the likelihood of simulator sickness, a finding that would be expected because use of the freeze function is thought to be nauseogenic (Kennedy et al., 1987a). This is particularly noticeable to aviators if the scene is frozen while in a turn or climbing turn.

There was no variance of the "motion system on/off" variable (motion system was on for all flights) and so a correlation could not be computed. However, it was the general consensus among pilots and instructor operators that flying the simulator with the motion system off was far more provocative.

Training variables

It can be seen that pilots who experienced greater symptomatology were more likely to rate their symptoms as being worse than those they experience in the actual aircraft. This suggests that simulator sickness symptomatology is more severe than symptomatology experienced in the actual aircraft.

It also can be seen that greater symptomatology was associated with a less favorable rating on whether simulator-induced discomfort disrupts training. A fuller appreciation of this relationship can be seen in Table 7 which shows the frequencies for this variable. The majority of pilots felt that simulator-induced discomfort does not hamper training. However, as the correlation indicates, those who experienced symptomatology tended to give a less favorable rating.

Table 7.

Frequencies for variable "discomfort hampers training"

Simulator-induced discomfort hampers training

Response	f	Percent
Strongly disagree	55	80.9
Tend to disagree	10	14.7
Neutral	2	2.9
Tend to agree	1	1.5
Strongly agree	0	0.0
Observations	68	

Symptomatology by mission and seat

Mission

Table 8 shows that night vision goggles (NVG) and proficiency training were associated with greater symptomatology than instrument training. Instrument training is associated with minimal out-the-window viewing which could account for the low incidence of symptomatology. It would be comparable to training in a nonvisual simulator. In addition, Table 9 shows that instrument training was associated with 0.0 percent NOE flight and with fewer freezes than the other two missions categories, which also would tend to reduce the severity of sickness.

Table 8.

Mean SSQ scores by mission

SSQ scale	Proficiency	Instrument	NVG
Nausea	109.5 (14.7)	103.5 (10.6)	109.2 (12.6)
Visuomotor	111.4 (14.3)	109.4 (14.1)	114.0 (13.7)
Disorientation	107.0 (9.4)	104.2 (11.3)	106.2 (11.1)
Total severity	111.2 (14.1)	107.1 (13.1)	112.2 (12.8)
Observations	12	33	27

Table 9.

Scenario content data (means and standard deviations) for different missions flown in the CH-47 simulator

	Mission		
	Proficiency	Instrument	NVG
Percent NOE	1.7 (5.8)	0.00 (0.0)	16.6 (21.4)
Freeze	6.2 (5.7)	1.5 (1.5)	5.2 (7.2)
Observations	12	33	27

Seat

SSQ scores are broken out by seat in Table 10. Comparisons of severity of simulator sickness for pilots and copilots (only three individuals flew in both seats and were not included in these analyses), show that aircrew training in the pilot seat are at most risk for simulator sickness. A comparison of missions flown for these categories (Table 11) shows that aircrew training in the copilot seat flew a greater percentage of proficiency and NVG missions and, in addition, had a greater overall mean percentage of NOE flight, all of which was associated with greater severity of sickness (Table 6). Thus, other than the average number of freezes, data in Table 11 suggest that aircrew training in the copilot seat should be more at risk for simulator sickness. It is possible that differences in susceptibility between the two groups could account for the difference.

Table 10.

Mean (standard deviation) SSQ scores by seat

SSQ scale	Seat CP	Pilot	IO
Nausea	104.2 (7.6)	109.3 (14.9)	101.1 (3.2)
Visuomotor	109.3 (12.9)	113.8 (15.1)	105.9 (8.3)
Disorientation	102.6 (5.5)	107.9 (13.5)	101.6 (4.6)
Total severity	106.9 (10.2)	112.6 (15.1)	103.7 (5.6)
Observations	27	39	9

Table 11.

Mission and scenario content data
for copilots and pilots

	Seat CP	Pilot
Percent aircrew flying key missions:		
Proficiency	14.8	15.4
Instruments	37.0	48.7
NVG	40.7	33.3
Means (standard deviations) for key scenario variables:		
Percent NOE	8.89 (17.0)	6.05 (15.8)
Freeze	3.22 (2.94)	4.55 (7.25)
Observations	27	39

There were nine observations of instructor operators. These data suggest that, under the conditions of the simulation flights flown by these individuals, instructor operators are at low risk for simulator sickness. However, experimenter interviews with instructor operators revealed they may experience symptomatology after several periods in the simulator and if they have not had enough sleep the previous night.

Discussion

The principal goal in this field study was to assess the incidence of simulator sickness in the CH-47 flight simulator. The results show that this simulator produces a lower incidence of simulator sickness than the three other Army visually coupled flight simulators. However, as mentioned previously, 18 percent of the sample may be at risk for simulator-induced posteffects. As in other systems, eyestrain and headache were leading symptoms of asthenopia, while fatigue and sweating were leading symptoms associated with motion sickness.

Of possible impact on the results are the sample of aviators surveyed and the scenarios flown. None of the aviators sampled were in a training/qualification status. All were rated in the CH-47 and flying for continuation and proficiency. Therefore, it could be assumed the scenarios flown were less structured and flown by aviators familiar with both the aircraft and the simulator. Also, the CH-47 is a heavy aircraft that does not fly a large amount of high maneuver content missions. This could lead to lower amounts of provocative scene variables such as low-level flight, maneuvering in close proximity to the ground, and high speed turns.

In reviewing Table 11, it is noted that 48 percent of the pilots' and 37 percent of the copilots' missions were under instrument conditions. Such a large percentage of time spent with no scene content could account for some of the lower SSQ scores. If, in fact, the aviators are opting to fly under instrument conditions to avoid the discomfort associated with NVG or low-level flight, then there is cause for concern.

The use of NVGs in the CH-47 simulator is associated with higher scores on the SSQ as seen in Table 8. The NVGs in actual flight tend to cause problems due to their added weight, limited field-of-view, and degraded visual qualities. Moreover, because they restrict the field-of-view, NVGs may cause recalibration of the vestibulo-ocular reflex. When combined with the artificial environment of the simulator, it is not surprising to see a relatively higher incidence of visuomotor symptoms.

As stated in the methods section, the researchers did not exercise any control over the flights in the simulator. In the absence of detailed programs of instruction (POI) or standardized flight scenarios, it is very difficult to accurately describe provocative flight conditions. Further, the amount of adaptation during the flight and on subsequent flights was not assessed. The time course of the symptoms experienced also was not possible to assess in the study. Therefore, symptomatology may be underestimated for some earlier flights and overestimated for later flights. In general, the manner in which the questionnaires were scored tends to be conservative. These topics should be studied under controlled conditions.

The method of testing postural stability used in this study was successful in demonstrating postexposure ataxia in a previous study (Gower et al., 1987). However, due to the operational considerations of the current study, none of the aviators received sufficient practice to reach a level of proficiency on the tests prior to simulator exposure. It is possible the lack of significant decrements on these tests was due, in part, to the masking of simulator effects by practice effects. Experimenter records indicated that some aircrews felt unsteady after their simulator exposure but, nevertheless, performed well on the tests. Further controlled studies with stabilimeter measurement should be considered.

Recommendations

In view of the results of this study and other studies conducted in Army visually-coupled flight simulators, it is our recommendation that:

a. Continued caution be exercised with those aviators flying in this simulator. Also, this should include adherence to the 6-hour wait period advocated in USAARL No. 88-1.

b. Commanders should, in conjunction with their flight surgeons, implement monitoring of their aviators to assess those who have demonstrated problems with the simulator environment. Those who do experience problems should restrict flight in the actual aircraft for at least one night's rest to allow them to dissipate. Strict adherence to the guidelines published in Kennedy et al. (1987a) should be followed for aviators experiencing problems until they adapt to the simulator.

c. Calibration and alignment of the visuals be accomplished regularly and as a part of routine maintenance. Consideration should be given to having the visual system of this and other Army simulators checked for excessive flicker, accommodation and vergence demands, unequal accommodative demands, and accommodation/vergence conflict.

d. Further controlled studies be conducted to ascertain the role of aviator susceptibility and its part in the phenomenon of simulator sickness. These studies also may involve the use of psychophysiological measurements in order to objectively determine the time course of the aviator's simulator sickness experience. One question still not answered is the actual time course of the symptoms experienced by the aviators in the simulator and the recurrence of delayed effects. Anecdotal data continues to be received indicating there is a part of the aviation population that experience delayed problems beyond the simulator exposure and for periods of time that exceed 6-8 hours.

e. Studies be conducted to determine which scenarios are linked with simulator sickness and methods to prepare aviators to deal with those scenarios. A correlation of simulator sickness with actual flight experience under similar conditions should be determined in side-by-side studies conducted in the simulator and in the aircraft.

f. Studies be conducted to ascertain the period of time an aviator should wait postflight before piloting an actual aircraft or even driving a car.

g. Commanders and supervisors should review the POIs being flown in their particular simulator devices against the required missions that should be flown in the device. If aviators are avoiding the simulator for reasons of simulator sickness, then a larger problem exists than is indicated in this report. The use of a visually-coupled flight simulator for instrument training should be a cause for concern if it reaches proportions above the requirements.

References

Allgood, G. O., Kennedy, R. S., Van Hoy, B. H., Lilienthal, M. G., and Hooper, J. H. 1987. The effects of very-low frequency vibrations on simulator sickness. Paper presented at the 58th Annual Scientific Meeting of the Aerospace Medical Association, Las Vegas, Nevada.

Baltzley, D. R., Kennedy, R. S., Berbaum, K. S., Lilienthal, M. G., and Gower, D. W. 1989. The time course of postflight simulator sickness symptoms. Aviation, space, and environmental medicine. In press.

Casali, J. G. 1986. Vehicular simulation-induced sickness: Volume I: An overview (NTSC-TR-86-010). Orlando, FL: Naval Training Systems Center. NTIS No. AD A173-904.

Colehour, J. K., and Graybiel, A. 1966. Biochemical changes occurring with adaptation to accelerative forces during rotation. Pensacola, FL: NASA/U.S. Naval Aerospace Institute. Joint Report No. NAMI-959.

Crampton, G. H., and Young, F. A. 1953. The differential effect of a rotary visual field on susceptibles and nonsusceptibles to motion sickness. Journal of comparative and physiological psychology. 46:451-453.

Crowley, J. S. 1987. Simulator sickness: A problem for Army aviation. Aviation, space, and environmental medicine. 58(4):355-357.

Department of Defense. 1981. Human engineering design criteria for military systems, equipment and facilities. Military Standard 1472C. Washington, D.C.

Department of the Army. 1982. Operator's manual for the Army CH-47D helicopter. Washington, DC: Headquarters, Department of the Army. TM 55-1520-240-10.

Ebenholtz, S. M. 1988. Sources of asthenopia in Navy flight simulators (TCN 87-635). Research Triangle Park, NC: U.S. Army Research Office.

Fowlkes, J. E., Kennedy, R. S., and Baltzley, D. R. 1989. Simulator sickness in the TH-57C helicopter flight simulator. Orlando, FL: Essex Corporation.

Fregley, A. R., and Graybiel, A. 1965. Residual effects of storm conditions at sea upon the postural equilibrium functioning of vestibular normal and vestibular defective human subjects. Pensacola, FL: Naval School of Aviation Medicine. Report No. NSAM-935.

Fregly, A. R., and Kennedy, R. S. 1965. Comparative effects of prolonged rotation at 10 rpm on postural equilibrium in vestibular normal and vestibular defective human subjects. Aerospace medicine, 36:1160-1167.

Gower, D. W., Lilienthal, M. G., Kennedy, R. S., Fowlkes, J. E., and Baltzley, D. R. 1987. Simulator sickness in the AH-64 Apache combat mission simulator. Fort Rucker, AL: U.S. Army Aeromedical Research Laboratory. USAARL Report No. 88-1.

Graybiel A., and Lackner, J. R. 1983. Motion sickness acquisition and retention of adaption effects compared in three motion environments. Aviation, space, and environmental medicine. 54:307-11.

Homick, J. L., and Reschke, M. F. 1977. Postural equilibrium following exposure to weightless space flight. Acta oto-laryngologica. 83:455-464.

Kennedy, R. S. 1975. Motion sickness questionnaire and field independence scores as predictors of success in Naval aviation training. Aviation, space, and environmental medicine. 46:1349-1352.

Kennedy, R. S., Berbaum, K. S., and Frank, L. H. 1984. Visual distortion: The correlation model (Technical Report No. 841595). Proceedings of the SAF Aerospace Congress and Exhibition, Long Beach, CA.

Kennedy, R. S., Berbaum, K. S., Lilienthal, M. G., Dunlap, W. P., Mulligan, W., and Funaro, J. 1987a. Guidelines for alleviation of simulator sickness symptomatology (NTSC-TR-87-007). Orlando, FL: Naval Training Systems Center.

Kennedy, R. S., and Frank, L. H. 1986. A review of motion sickness with special reference to simulator sickness. Paper presented at the 65th annual meeting of the Transportation Research Board, Washington, DC.

Kennedy, R. S., Lilienthal, M. G., Berbaum, K. S., Baltzley, D. R., and McCauley, M. E. 1987b. Simulator sickness in 10 U.S. Navy flight simulators. Orlando, FL: Naval Training Systems Center. NTSC-TR-87-008.

Lane, N. E., and Kennedy, R. S. 1988. A new method for quantifying sickness: Development and application of the simulator sickness questionnaire (SSQ) (EOTR 88-7). Orlando, FL: Essex Corporation.

Lenel, J. C., Berbaum, K. S., and Kennedy, R. S. 1987. A motion sickness history questionnaire: Scoring key and norms for young adults. Orlando, FL: Essex Corporation. EOTR 87-3.

Link Flight Simulation Corporation. 1987. Operator's manual for the CH-47D (Chinook) flight simulator device 2B31A. Singer-Link Flight Simulation Corporation. TM 55-6930-212-10.

Link Flight Simulation Corporation. 1987. Organizational and intermediate maintenance manual for CH-47D (Chinook) flight simulator device 2B31A, visual system. Binghamton, NY: Singer-Link Flight Simulation Corporation, 1 November 1987. TM-55-6930-212-23-3.

McClure, J. A., and Fregly, A. R. 1972. Forehead sweating during motion sickness. Pensacola, FL: Naval Aerospace Medical Research Laboratory. NAMRL-1157 (NTIS No. AD A743-975).

Money, K. E. 1970. Motion sickness. Psychological reviews. 50(1), 1-39.

Morrissey, S. J., and Bittner, A. C., Jr. 1986. Vestibular, perceptual, and subjective changes associated with extended VDU use: A motion sickness syndrome? In W. Karkowski (Ed.), Trends in ergonomics/human factors III. New York: North-Holland.

Oman, C. M. 1980. A heuristic mathematical model for the dynamics of sensory conflict and motion sickness. Cambridge, MA: Man-Vehicle Laboratory, Center for Space Research. Report No. MVT-80-1.

Reason, J. T., and Brand, J. J. 1975. Motion sickness. New York: Academic Press.

Stern, R. M., Koch, K. L., Stewart, W. R., and Lindblad, I. M. 1987. Spectral analysis of tachygastria recorded during motion sickness. Gastroenterology. 92:92-97.

Teixeira, R. A., and Lackner, J. R. 1979. Optokinetic motion sickness: Attenuation of visually-induced apparent self-rotation by passive head movements. Aviation, space, and environmental medicine. 50(3), 264-266.

Thomley, K. E., Kennedy, R. S., and Bittner, A. C., Jr. 1986. Development of postural equilibrium tests for examining environmental effects. Perceptual and motor skills. 63: 555-564.

Ungs, T. J. 1987. Simulator sickness: Evidence of long-term effects. Paper presented at the annual Human Factors meeting, New York.

Van Hoy, B. W., Allgood, G. O., Lilienthal, M. G., Kennedy, R. S., and Hooper, J. M. 1987. Inertial and control systems measurements of two motion-based flight simulators for evaluation of the incidence of simulator sickness. Proceedings of the IMAGE IV Conference. Phoenix, AZ.

Appendix A

Simulator sickness survey

Serial No.____________ Date______________

SIMULATOR SICKNESS SURVEY

This is a survey of simulator aftereffects being conducted for the U.S. Army Aeromedical Research Laboratory, Fort Rucker, Alabama, in cooperation with the Naval Training Systems Center. The purpose of the survey is to determine the incidence of simulator aftereffects such as nausea or imbalance occurring in visually coupled flight simulators (UH-60, AH-1 CH-47).

We appreciate your cooperation in obtaining information about this problem. The results of the study will be used to improve the characteristics of future simulators. Your responses will be held in confidence and used statistically. Although we ask for your name on this page, no information will be reported by name. This cover page will be removed and all data will be identified by the coded serial number above.

Your Name ____________________________ Rank ________________

Date ________________________________ Unit ________________

Instructor ___________________________ (if in Qualification training)

Training Stage : Qualification __________ Continuation __________

Refresher __________ AAPART (Check Ride)__________

Mission __________

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Serial No.__________ Date____________

MOTION HISTORY QUESTIONNAIRE

1. Approximately, how many total flight hours as pilot and co-pilot do you have? (in all aircraft, civilian and military time inclusive)

a. Fixed Wing _____

b. Rotary Wing _____

2. How often would you say you get airsick?

Always ____ Frequently ____ Sometimes ____ Rarely ____ Never ____

3. a. How many total flight simulator hours? _______ (all except SFTS)

b. How many flight hours do you have in this this simulator? _____

4. How much experience have you had at sea aboard ships or boats?

Much ____ Some ____ Very Little ____ None ____

5. How often would you say you get seasick?

Always ____ Frequently ____ Sometimes ____ Rarely ____ Never ____

6. Have you ever been motion sick under any conditions other than the ones listed so far? No ____ Yes ____

If "Yes," under what conditions? ______________________________

____

7. In general, how susceptible to motion sickness do you feel you are?

Extremely ____ Very ____ Moderately ____ Minimally ____ Not at all ____

8. Have you been nauseated FOR ANY REASON during the past 8 weeks?

No ____ Yes ____ If "Yes," explain ____________________________

____

Serial No.__________ Date__________

9. When you were nauseated _r any reason (including flu, alcohol, etc.), did you vomit?

Easily ____ Only with difficulty ____ Retch and finally vomited with great difficulty ____

10. If you vomited while experiencing motion sickness, did you:

a. Feel better and remain so? ______
b. Feel better temporarily, then vomit again? ______
c. Feel no better, but not vomit again? ______
d. Other - specify ______________________________

____

11. If you were in an experiment where 50% of the subjects get sick, what do you think your chances of getting sick would be?

Almost certainly would ____ Probably would ____ Probably would not ____ Almost certainly could not ____

12. Would you volunteer for an experiment where you knew that: (Please answer all three)

a. 50% of the subjects did get motion sick? Yes ____ No ____
b. 75% of the subjects did get motion sick? Yes ____ No ____
c. 85% of the subjects did get motion sick? Yes ____ No ____

13. Most people experience slight dizziness (not a result of motion) 3 to 5 times a year. The past year you have been dizzy:

more than this ____ the same as ____ less than ____ never dizzy ____

14. Have you ever had an ear illness or injury which was accompanied by dizziness and/or nausea? Yes ____ No ____

Serial No.____________Date______________

15. Listed below are a number of situations in which some people have reported motion sickness symptoms. In the space provided, check (a) your PREFERENCE for each activity (that is, how much you like to engage in that activity), and (b) any SYMPTOM(S) you may have experienced at any time, past or present. You may list more than one symptom for each activity.

SITUATIONS	PREFERENCE				SYMPTOMS												
	Like	Neutral	Dislike		Vomited	Nausea	Stomach Awareness	Increased Salivation	Dizziness	Drowsiness	Sweating	Pallor	Vertigo	Awareness of Breathing	Headache	Other Symptoms	None
Aircraft																	
Flight Simulator																	
Roller Coaster																	
Merry-Go-Round																	
Other Carnival Devices																	
Automobiles																	
Long Train or Bus Trips																	
Swings																	
Hammocks																	
Gymnastic Apparatus																	
Roller/Ice Skating																	
Elevators																	
Cinerama or Wide-Screen Movies																	
Motorcycles																	

* Stomach awareness refers to a feeling of discomfort that is preliminary to nausea

Serial No.__________ Date______________

16. If you have ever experienced simulator sickness or discomfort (or any other aftereffect):

a. What simulator was it? ______________________________

b. What were the symptoms? ______________________________

____

c. If they went away and then came back, describe what events surrounded their return. ______________________________

____

d. How long did they last immediately post-flight? ______________

e. How long did they last if they went away and then came back? ______

d. What do you think caused the problem? ______________________

____

END OF MOTION HISTORY QUESTIONNAIRE

Serial No.__________ Date______________

PRE-FLIGHT BACKGROUND INFORMATION

Instructions: Please fill this page out BEFORE you go into the simulator. Fill in the blanks or circle the appropriate item.

1. Start time for your flight: ________ Expected length of flight ______

2. Seat you will be in for the simulator flight (Circle only one):

   Copilot Gunner (CPG) (AH-1 only)

   Copilot (CP)

   Pilot (P)

   Instructor/Operator (IO)

   CPG seat for first part of flight, then P seat

   P seat for first part of flight, then CPG seat

3. Type of mission: Proficiency / Instrument / Tactics / Other ____

4a. Aircraft flight hours last 2 months ________________

4b. How many days has it been since your last flight IN THE AIRCRAFT? ____

5a. Simulator flights last 3 months ______ Simulator hours last 3 days ____

6c. How many days has it been since your last flight IN THIS SIMULATOR? ____

GO TO NEXT PAGE

Serial No._ __________Date______________

PRE-FLIGHT PHYSIOLOGICAL STATUS INFORMATION

Instructions: Please fill this out BEFORE you go into the simulator.

1. Are you in your usual state of fitness: YES NO

   If not, what is the nature of your illness (flu, cold, etc.)?

   ____

2. Please indicate all medications you have used in the past 24 hours:

   a) NONE ____________

   b) Sedatives or tranquilizers ____________

   c) Aspirin, Tylenol, other analgesics ____________

   d) Antihistamines ____________

   e) Decongestants ____________

   f) Other (specify): ________________ ____________

3. Have you used any tobacco products:

   In the past 24 hours? YES NO

   In the past 48 hours? YES NO

4. Have you had any beverage containing alcohol:

   In the past 24 hours? YES NO

   In the past 48 hours? YES NO

5. How many hours sleep did you get last night? ________ (Hours)

   Was this amount sufficient? YES NO

GO TO NEXT PAGE

Serial No.__________ Date______________

PRE-FLIGHT SYMPTOM CHECKLIST

Instructions: Please fill this out BEFORE you go into the simulator. Circle below if the symptoms apply to you right now. (After your simulator flight, you will be asked these questions again.)

1.	General discomfort	None	Slight	Moderate	Severe
2.	Fatigue	None	Slight	Moderate	Severe
3.	Boredom	None	Slight	Moderate	Severe
4.	Drowsiness	None	Slight	Moderate	Severe
5.	Headache	None	Slight	Moderate	Severe
6.	Eye strain	None	Slight	Moderate	Severe
7.	Difficulty focusing	None	Slight	Moderate	Severe
8.	a. Salivation increased	None	Slight	Moderate	Severe
	b. Salivation decreased	None	Slight	Moderate	Severe
9.	Sweating	None	Slight	Moderate	Severe
10.	Nausea	None	Slight	Moderate	Severe
11.	Difficulty concentrating	None	Slight	Moderate	Severe
12.	Mental depression	No	Yes		
13.	"Fullness of the Head"	No	Yes		
14.	Blurred vision	No	Yes		
15.	a. Dizziness with eyes open	No	Yes		
	b. Dizziness with eyes closed	No	Yes		
16.	Vertigo	No	Yes		
17.	*Visual flashbacks	No	Yes		
18.	Faintness	No	Yes		
19.	Aware of breathing	No	Yes		
20.	**Stomach awareness	No	Yes		
21.	Loss of appetite	No	Yes		
22.	Increased appetite	No	Yes		
23.	Desire to move bowels	No	Yes		
24.	Confusion	No	Yes		
25.	Burping	No	Yes	No. of times	______
26.	Vomiting	No	Yes	No. of times	______
27.	Other______________				

* Visual illusion of movement or false sensations similar to aircraft dynamics, when not in the simulator or the aircraft.

** Stomach awareness is usually used to indicate a feeling of discomfort which is just short of nausea.

STOP HERE! The test director will tell you when to continue

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Serial No.__________ Date______________

POST-FLIGHT SYMPTOM CHECKLIST

Instructions: Circle below if any symptoms apply to you right now.

1.	General discomfort	None	Slight	Moderate	Severe
2.	Fatigue	None	Slight	Moderate	Severe
3.	Boredom	None	Slight	Moderate	Severe
4.	Drowsiness	None	Slight	Moderate	Severe
5.	Headache	None	Slight	Moderate	Severe
6.	Eye strain	None	Slight	Moderate	Severe
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21.	Loss of appetite	No	Yes		
22.	Increased appetite	No	Yes		
23.	Desire to move bowels	No	Yes		
24.	Confusion	No	Yes		
25.	Burping	No	Yes	No. of times ______	
26.	Vomiting	No	Yes	No. of times ______	
27.	Other ______				

28. Would you describe the symptoms above as

SAME AS
WORSE THAN
NO DIFFERENCE

from flight in the actual aircraft under the same conditions you experienced in the flight just completed.

* Visual illusion of movement or false sensations similar to aircraft dynamics, when not in the simulator or the aircraft.

** Stomach awareness is usually used to indicate a feeling of discomfort which is just short of nausea.

GO TO THE NEXT PAGE

Serial No.__________ Date______________

POST-FLIGHT INFORMATION

Instructions: Please fill out this page AFTER you have completed your flight.

1. The simulator was flown with the following systems ON/OFF:

Visual System	ON	OFF	DEGRADED
Motion System	ON	OFF	DEGRADED
Seat Shaker	ON	OFF	DEGRADED
Sound	ON	OFF	DEGRADED

2. Were any other systems turned off for a part of the flight? YES NO

   If YES, which system(s) ______________________________

3. Were all the instruments that you needed for this flight operational?

   YES NO

4a. The collective control was: EXCELLENT/ GOOD/ FAIR/ BAD .

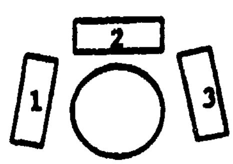
4b. The cyclic pitch control was: EXCELLENT/ GOOD/ FAIR/ BAD .

4c. The cyclic roll control was: EXCELLENT/ GOOD/ FAIR/ BAD .

4d. The anti-torque control was: EXCELLENT/ GOOD/ FAIR/ BAD .

5. Were any of the "windows" not on for the flight? YES NO

   If YES, which one? (Circle inoperable windows on diagram below)



6. How long did your flight period last? ______ Hours

7. Proportion (in percent) of the time spent: Low-Level ________

   Nap-of-the-Earth (NOE) ______ Upper Air Work: ______ Instrument______

GO TO NEXT PAGE

Serial No.__________Date__________

8. Type of flight conditions: Night / Dusk / Instrument / DAY VFR /

9. Percentage of time looking out of windows ________________

10. Percentage of time operating TSU heads down ________________

11. Number of times the simulator was put on freeze ____________

12. Number of times any scene was replayed ________________

13. Number of impacts/ near hits from enemy ____________

14. Number of impacts with ground: ________

15. Number of landings attempted: ________

16. The time now __________

17. Did you have to wait long periods while in the simulator for any reason?

    YES ____ NO ____ If YES, how long? _____

18. In terms of training effectiveness, this simulator accomplishes its purpose of training me to be more proficient at flight skills?

    Please circle the number which most closely corresponds to your feelings about the statement above.

5	4	3	2	1
Strongly Agree	Tend to agree	Neutral	Tend to agree	Strongly Disagree

19. If you experienced discomfort of some degree in the simulator (enough to mark one or more of the Post-Flight Symptoms), did their severity hamper your training during the flight? Circle the number which most closely describes your experience in today's flight.

5	4	3	2	1
Complete Disruption		Moderate Disruption		No Disruption

20. Scene Disturbances:

    Describe any disruptive visual system problems that you observed:

____

____

Serial No.____________Date_______________

Describe any bothersome visual traits you would like to see corrected:

Describe any disruptive motion system problems that you observed:

Describe any bothersome motion system traits you would like corrected:

Serial No. ____________ Date ________________

POSTURAL EQUILIBRIUM TEST DATA SUMMARY SHEET

BEFORE

WOFEC						X= ________
SOPLEC						X= ________
SONLEC						X= ________

AFTER

WOFEC						X= ________
SOPLEC						X= ________
SONLEC						X= ________

COMMENTS:

PREFERRED LEG- LEFT____ RIGHT____

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Appendix B

Variable descriptions

Variable	Description	Code
Pilot variables		
Simulator hours	Total hours in visual simulators	Number of hours
Enough sleep	Was the amount of sleep previous night sufficient?	1=Yes, 2=No
Simulator sickness	Have you ever experienced simulator sickness?	1=Yes, 0=No
Systems on/off?	Were other systems off during the flight?	1=Yes, 2=No
Collective control	How was the collective control?	1=Excellent 2=Good 3=Fair, 4=Bad
Pitch control	How was the pitch control?	1=Excellent 2=Good, 3=Fair, 4=Bad
Torque Control	How was the torque control?	1=Excellent 2=Good 3=Fair, 4=bad
Percent nap-of-the-earth flight	Percent of flight spent in NOE flight	Percentage
Freeze	Number of times simulator put on freeze	Number of times

Training variables	Description	Code
Different from aircraft?	Are symptoms experienced the same or worse than those experienced in the actual aircraft?	1=Same, 2=Worse
Discomfort hamper training?	Discomfort experienced hampered training	1=Strongly disagree 2=Tend to disagree 3=Neutral 4=Tend to agree 5=Strongly agree

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