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Simulator Sickness in the UH-60 (Black Hawk) Flight Simulator

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The U.S. Army Aeromedical Research Laboratory conducted field studies of operational flight simulators to assess the incidence and severity of simulator sickness. Simulator sickness here refers to the constellation of motion sickness related symptoms that occur in simulators due to visual representation, motion base representation, or combination of the two representations of flight. The incidence rates and relative frequency of specific symptoms are presented. Correlational factors such as recent simulator experience, current state of health, overall flight experience, mission scenario, and flight dynamics are presented. This report ranks the Army's [illegible] simulators in comparison to the 10 Navy simulators studied by the Naval Training Systems Center, Orlando, Florida. The study further reinforces the need for studies to understand perceptual rearrangement, adaptation/readaptation, and pilot susceptibility to the effects of simulation. Design criteria for simulators, as well as those training guidelines necessary to cope with this phenomenon also must be addressed.

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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 in the Singer Link facility at 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 88-1 documents the results of that first study.

As reported in Baltzley et al. (1989, in press), 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, Alabama, 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 UH-60 simulator site at Fort Rucker.

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 1,200 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

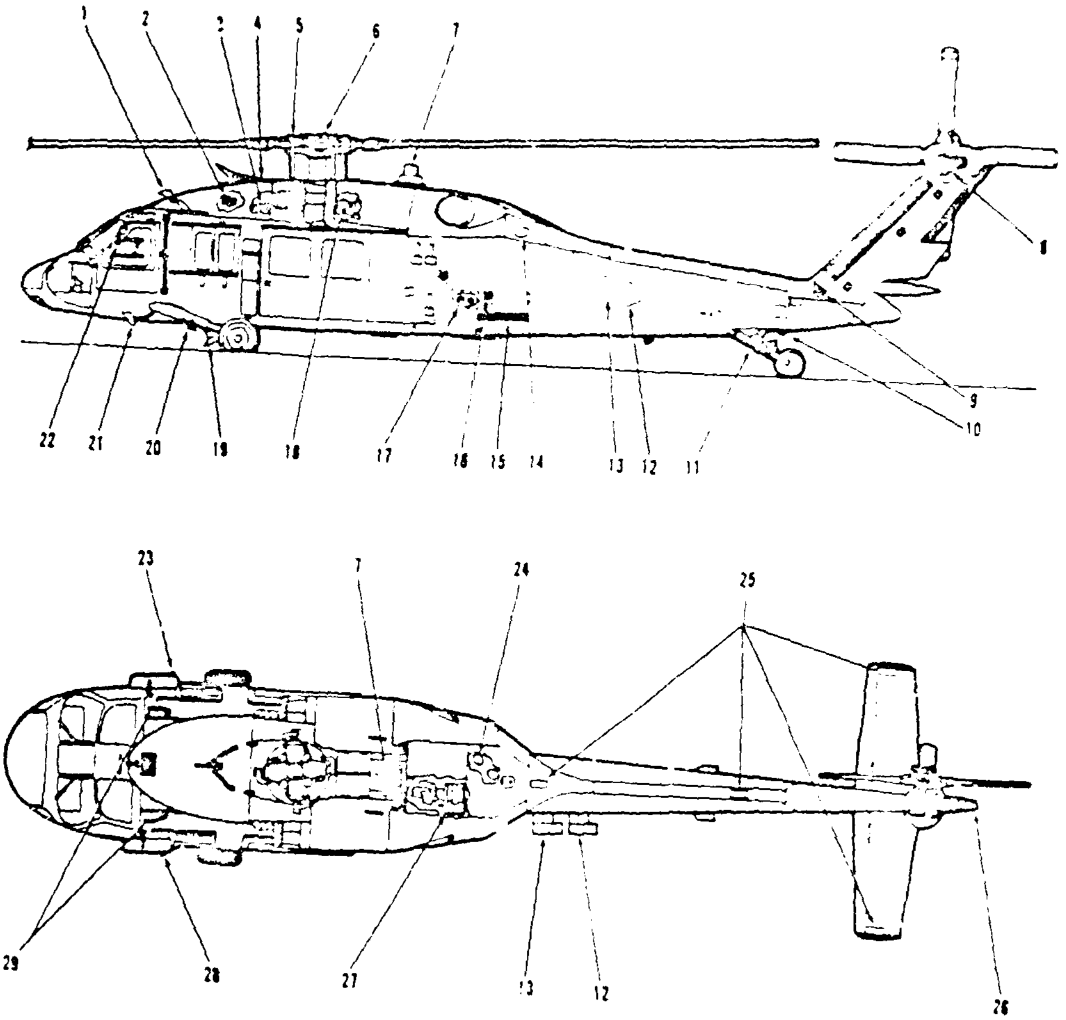
Description of the aircraft system

The UH-60A (Black Hawk) is a twin turbine engine, single rotor, semimonocoque fuselage, rotary-wing helicopter manufactured by the Sikorsky Aircraft Company (Figures 1, 2, and 3) (TM 55-1520-237-10). The aircraft is designed to operate with a crew of three: Pilot, copilot, and crew chief. In that configuration, it can carry 11 combat equipped soldiers. Alternate seating arrangements can be made to seat 14. In addition, the aircraft also can carry internal and external cargo. The primary mission of the aircraft is the transport of troops, supplies, and equipment. Other missions include training, mobilization, concept development as well as medical evacuation and disaster relief. The EH-60A aircraft is a specially-outfitted aircraft used for electronic surveillance and electronics countermeasure functions. When operating with the medical evacuation litter carousel installed, the aircraft operates with a crew of four, the additional crewmember being a medical aidman. The EH-60 uses a crew of four with the additional crewmember to operate the electronic warfare devices.

The main rotor system has four blades which are constructed of titanium and fiberglass. Propulsion is supplied by two T700-GE-700 engines operating in parallel. As opposed to the UH-1, which the Black Hawk is replacing in the inventory, the UH-60 has a landing gear system consisting of two main landing gear which are nonretractable and a tailwheel assembly, also nonretractable. Design of the UH-60 is closely equated with that specified in the Crashworthy Design Guide making the Black Hawk the first rotary-wing aircraft designed with crashworthiness included from the outset of the design process.

Armament consists of two 7.62 mm machine guns, one on each side of the helicopter, mounted inside the forward cabin (Figure 4). The weapons are mounted on a rotating arm assembly which allows the weapon to be locked outboard in the firing position or stowed inside the aircraft when the weapon is not needed. The weapons can be removed from the aircraft and used in ground defense with the bipod extended. Medical evacuation aircraft do not have that armament installed and the crew is protected by personal side arms only.

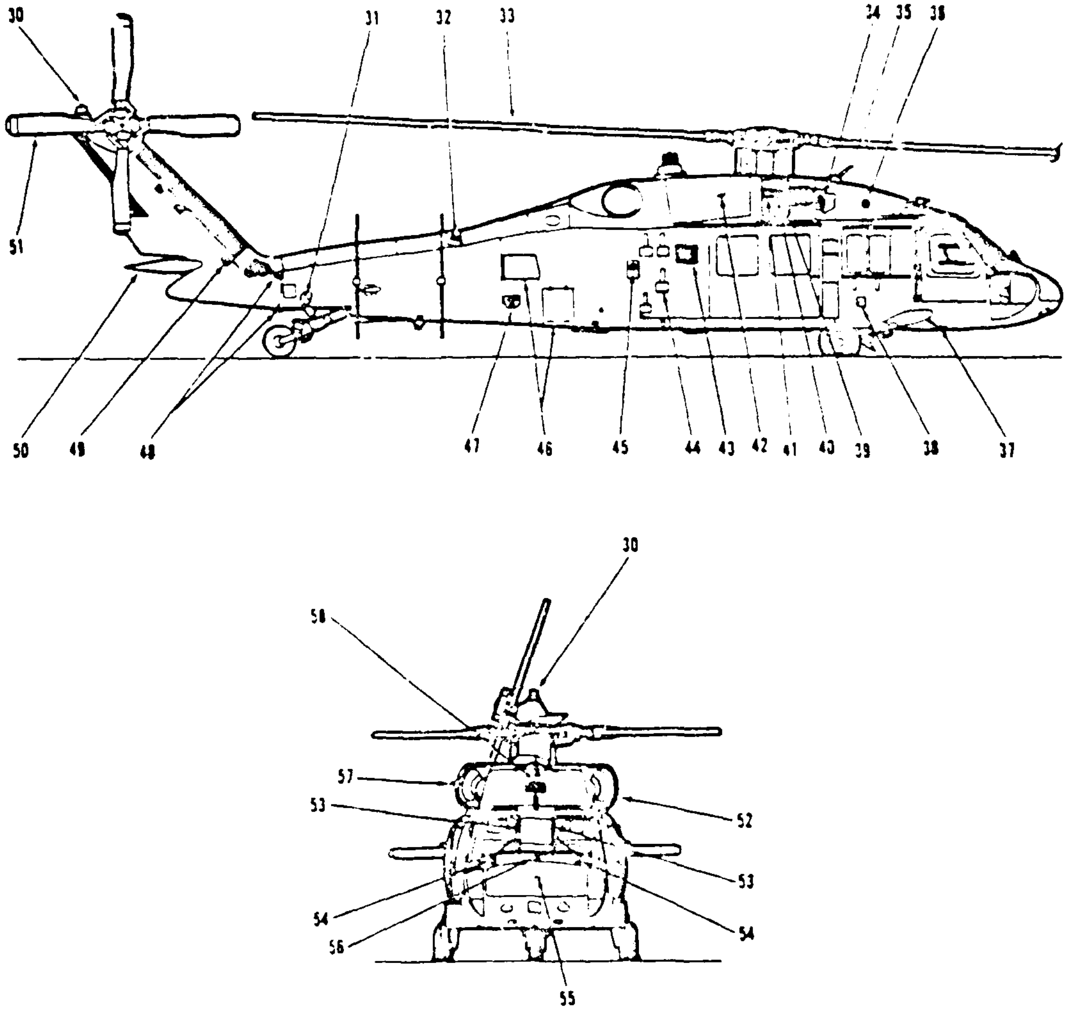
The gross weight of the aircraft is 20,250 pounds. Additional kit installations include extended range tanks, both internal and external, internal rescue hoists, the litter carousel for medical evacuation, infrared suppression, blade anti-icing/de-icing capability, blackout devices, winterization kits, and static/rappelling kit.



*1 PITOT CUTTER
2 BACKUP HYDRAULIC PUMP
3 NO. 1 HYDRAULIC PUMP AND NO. 1 GENERATOR
*4 UPPER (ROTOR PYLON) CUTTER
5 MAIN ROTOR BIFILAR
6 MAIN ROTOR HEAD
7 INFRARED COUNTERMEASURE TRANSMITTER
8 TAIL ROTOR GEAR BOX
9 INTERMEDIATE GEAR BOX
10 AFT MAINTENANCE LIGHT RECEPTACLE
*11 TAIL LANDING GEAR DEFLECTOR
12 FLARE DISPENSER
13 CHAFF DISPENSER
14 APU EXHAUST PORT
15 COOLING AIR INLET PORT
16 PNEUMATIC PORT
17 PRESSURE AND CLOSED CIRCUIT REFUELING PORTS
18 NO. 1 ENGINE
*19 MAIN LANDING GEAR DEFLECTOR [illegible]
*20 LANDING GEAR JOINT DEFLECTOR
*21 STEP AND EXTENSION DEFLECTOR
*22 DOOR HINGE DEFLECTOR
23 RIGHT POSITION LIGHT (GREEN)
24 FIRE EXTINGUISHER BOTTLES
25 FORMATION LIGHTS
26 TAIL POSITION LIGHT (WHITE)
27 APU
28 LEFT POSITION LIGHT (RED)
29 PITOT TUBES

*ON HELICOPTERS EQUIPPED WITH WIRE STRIKE PROTECTION SYSTEM

Figure 1. General arrangement.



30 UPPER ANTICOLLISION LIGHT
31 TAIL WHEEL STRUT
32 TAIL DRIVE SHAFT
33 MAIN ROTOR BLADE (FOUR)
34 NO. 2 HYDRAULIC PUMP AND NO 2 GENERATOR
* 35 PYLON CUTTER
36 HEATER AIR INTAKE PORT
37 COCKPIT STEP (SAME BOTH SIDES)
38 EXTERNAL ELECTRICAL POWER RECEPTACLE
39 NO. 2 ENGINE
40 ICE DETECTOR
41 AMBIENT SENSE PORT
42 ENGINE FAIRING/WORK PLATFORM (SAME BOTH SIDES)
43 CONDENSER EXHAUST/STEP
44 STEPS (SAME BOTH SIDES)
45 GRAVITY REFUELING PORT (SAME BOTH SIDES)
46 AFT AVIONICS COMPARTMENT DOORS (ON HELICOPTERS EQUIPPED WITH AFT AVION. MPARTMENT)
47 IINS BLOWER INLE. .LTER
48 TAIL PYLON FOLD HINGES
49 TAIL PYLON SERVICE LADDER (SAME BOTH SIDES)
50 STABILATOR
51 TAIL ROTOR BLADE (FOUR)
52 ENGINE BAY AREA COOLING AIR INTAKE (SAME BOTH SIDES)
* 53 WINDSHIELD POST DEFLECTOR
* 54 WINDSHIELD WIPER DEFLECTOR
55 AVIONICS COMPARTMENT
56 OAT SENSOR
57 ICE DETECTOR
58 PYLON COOLING AIR INTAKE

* ON HELICOPTERS EQUIPPED WITH WIRE STRIKE PROTECTION SYSTEM

Figure 2. General arrangement (continued).

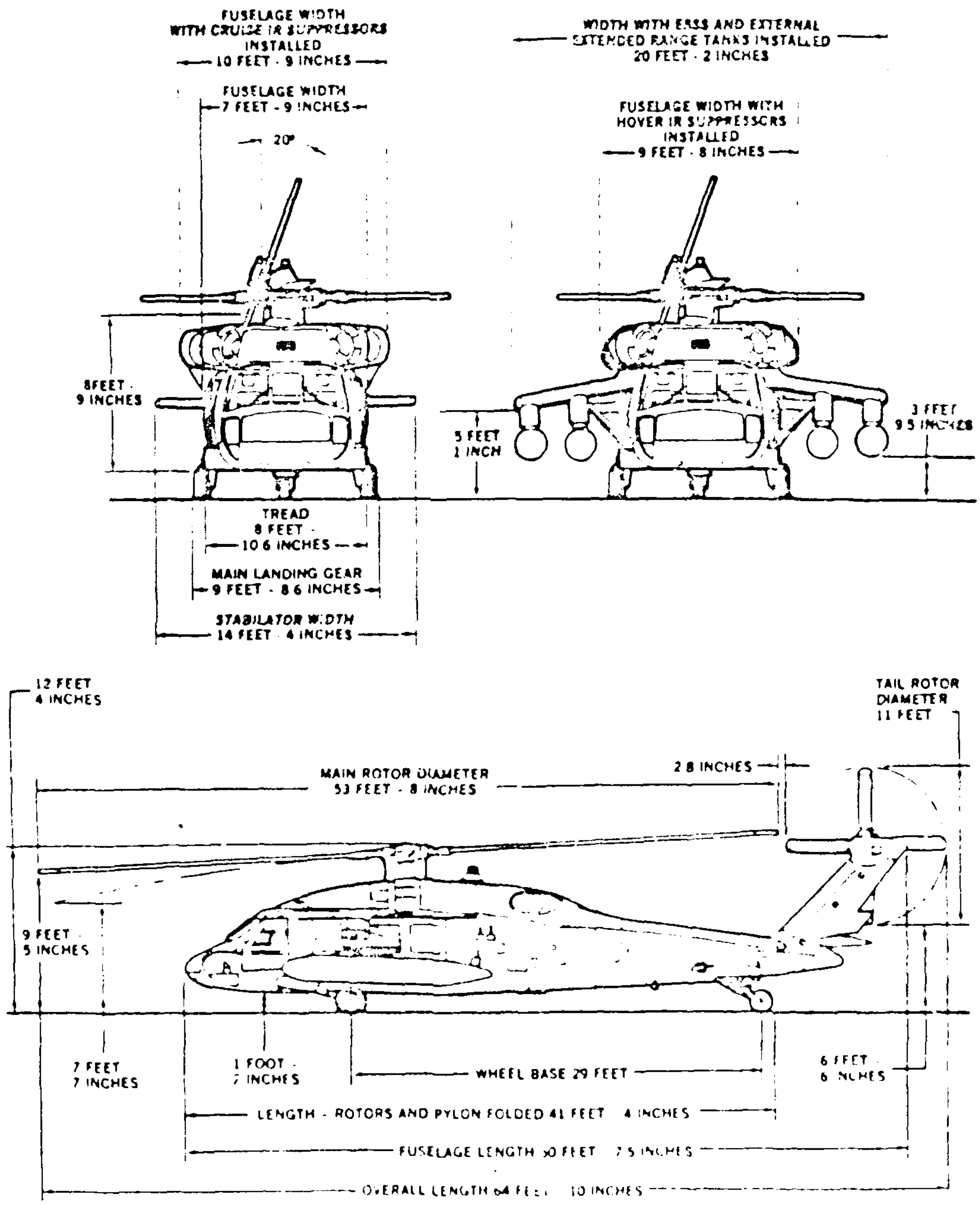


Figure 3. Principal dimensions.

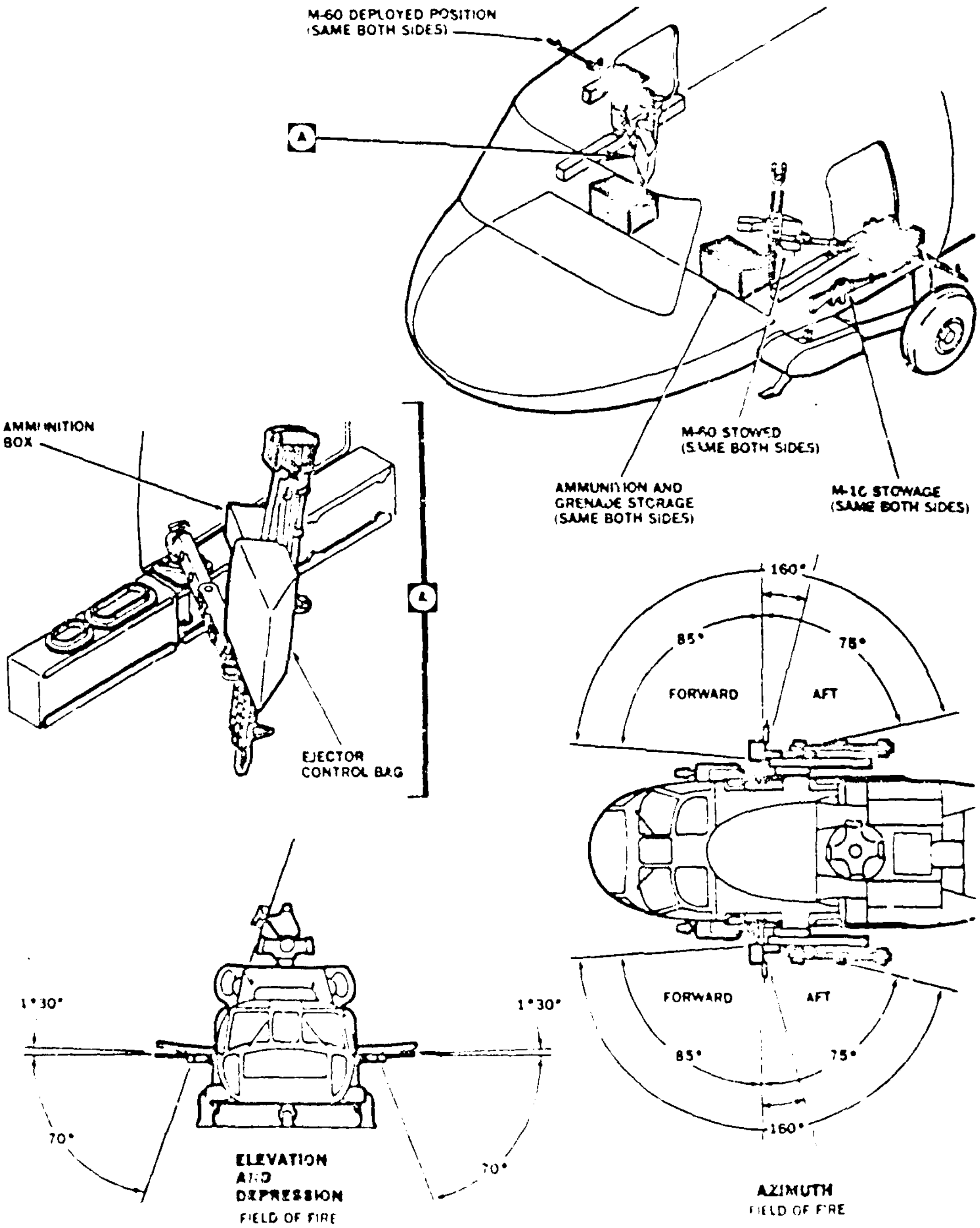


Figure 4. Machine gun M60D installation.

Both pilot and copilot have controls for flying the aircraft. The aircraft is fully instrument rated and can be flown without reference to the outside environment equally well from either pilot's station. The aircraft is equipped with an automatic flight control system (AFCS) which enhances the stability and handling qualities of the helicopter. This system is comprised of five subsystems. The stabilator subsystem positions the stabilator, which is located at the rear of the aircraft, by means of electromechanical actuators in response to collective, airspeed, pitch rate, and lateral acceleration inputs. A pitch bias actuator enhances the static stability in the longitudinal axis. The stability augmentation system (SAS) provides short term rate damping in the pitch, roll, and yaw axes. The trim/flight path stabilization systems serve as a basic autopilot providing control positioning and force gradient functions.

Currently, there are several systems under consideration for addition to the airframe for special missions. One of these is a forward looking infrared sensor (FLIR). In certain aircraft, this has been installed by means of a turret on the nose of the aircraft displaying information on a CRT-type screen on the instrument panel. Other devices which display the same information to the pilot by means of a full heads up display on the helmet visor also have been tested but not yet approved for acquisition. In conjunction with the Doppler navigation system installed in the aircraft, there are map sheet displays which gain information from the Doppler system and display the appropriate map sheet to the pilot on a kneeboard-type apparatus. These systems reflect the sophistication to which the Army has gone in the war-fighting capabilities of the aviation fleet.

Description of the simulation system

The UH-60 flight simulator is a motion-base device designed for training aviators in the use of the UH-60 Black Hawk helicopter (Figures 5 and 6). The device consists of a simulator compartment containing a cockpit with pilot and copilot stations, instructor operator (IO) station and an observer station, and a six-degree-of-freedom motion system. The simulator is equipped with a visual system that simulates natural environmental surroundings. A central computer system controls the operation of the simulator complex. The simulator is used to provide training in aircraft control, cockpit preflight procedures, instrument flight operations, visual flight operations, sling load operations, external stores subsystems, night vision goggles training, as well as those tactical skills necessary to conduct nap-of-the-earth (NOE) flight, low-level flight, and contour flight. A partial listing of training tasks that can be performed in the simulator is shown in Table 1.

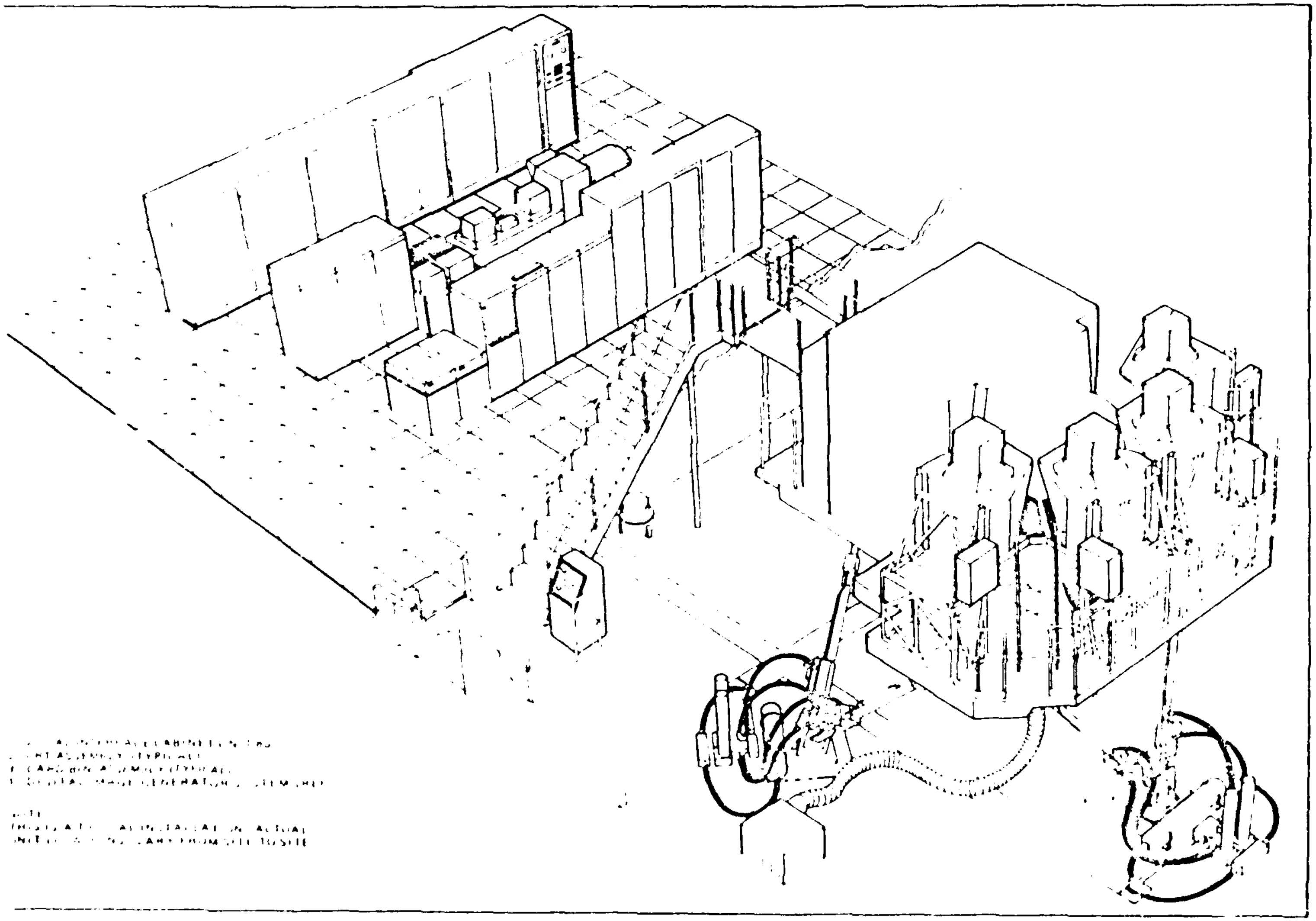


Figure 5. Typical UH-60 simulator installation.

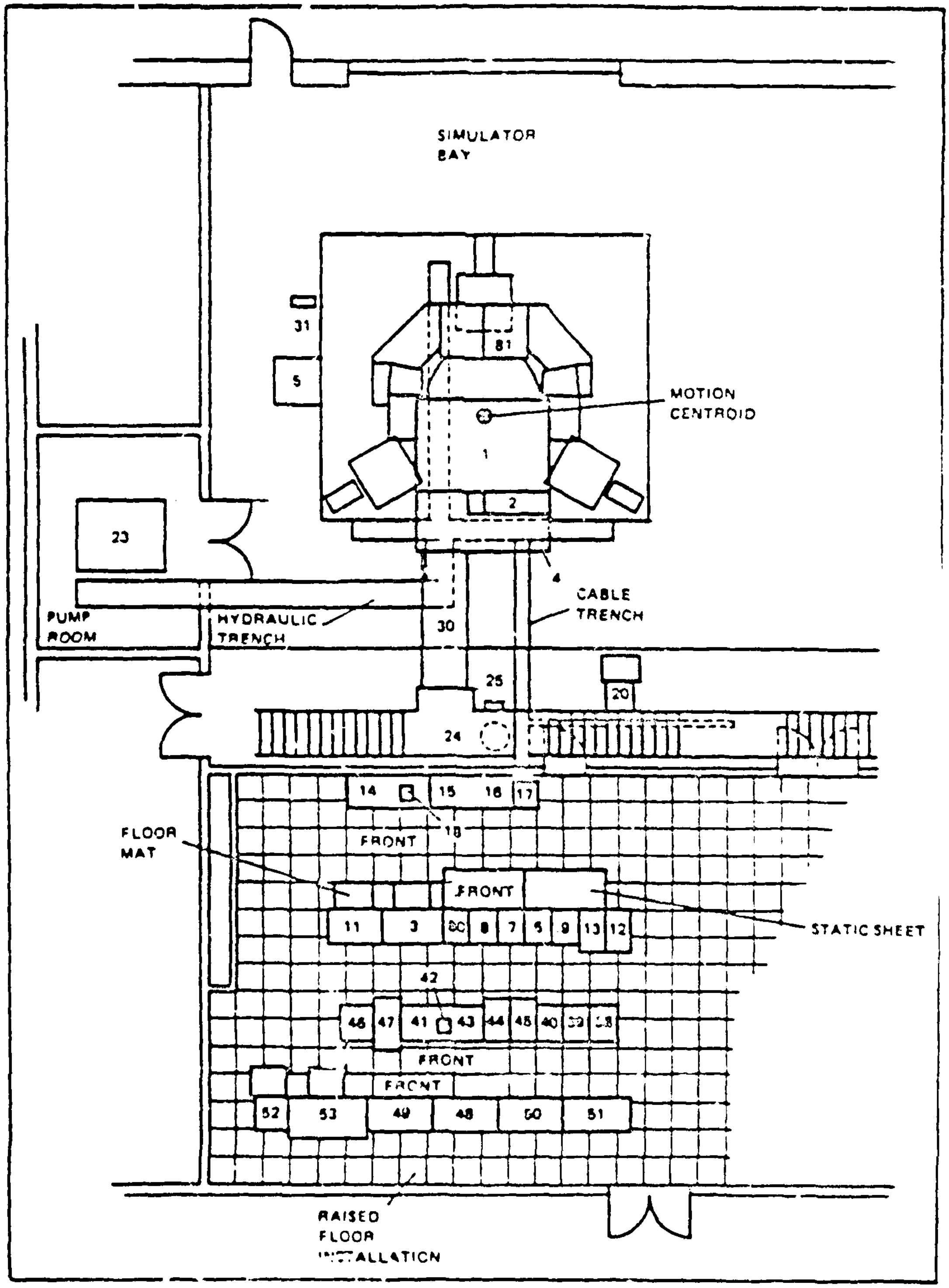


Figure 6. Typical UH-60 flight simulator.

UNIT (REF DES)	IDENTIFICATION	UNIT (REF DES)	IDENTIFICATION
1	PILOT COCKPIT	46	3-CHANNEL LINE PRINTER
2	GUNNER COCKPIT	47	(NOT USED)
3	(NOT USED)	48	MISCELLANEOUS CABINET NO. 2
4-1	PILOT MOTION PLATFORM	49	(NOT USED)
4-2	GUNNER MOTION PLATFORM	50	VISUAL INTERFACE COMPUTER (VIC)
5	(NOT USED)	51	VISUAL INTERFACE COMPUTER (VIC)
6	PILOT PERIPHERAL CABINET	52	VIC CRT
7	CPU A	53	VIC CRT
8	SELF-TEST LINKAGE CABINET	54	VIC DISK
9	DIGITAL LINKAGE CABINET	55	INTERPHONE JACK (NOT SHOWN)
10	ANALOG LINKAGE CABINET	56	INTERPHONE JACK (NOT SHOWN)
11	SELF-TEST LINKAGE CABINET	57	TERMINAL (CPU D)
12	POWER CABINET	58	TERMINAL (CPU E)
13	MISCELLANEOUS CABINET NO. 1	59	MAGNETIC TAPE UNIT
14	CPU C	60	1-CHANNEL VIDEO CONTROL CONSOLE
15	GUNNERS PERIPHERAL CABINET	61	1-CHANNEL POWER CABINET
16	CPU B	62	1-CHANNEL I/O EXPANSION CABINET
17	PRINTER/PLOTTER (CPU B)	63	1-CHANNEL DISK DRIVE
18	DISK DRIVE	64	1-CHANNEL DISK DRIVE
19	DISK DRIVE	65	1-CHANNEL VIDEO DISPLAY UNIT
20-1	PILOT MOTION CABINET	66	1-CHANNEL VIDEO DISPLAY UNIT
20-2	GUNNER MOTION CABINET	67	1-CHANNEL HARDCOPY UNIT
21	1-CHANNEL PRIORITY SECTOR PROCESSOR CABINET	68	3-CHANNEL VIDEO CONTROL CONSOLE
		69	3-CHANNEL POWER CABINET
22	1-CHANNEL FRAME CALCULATOR CABINET	70	3-CHANNEL CPU
23	1-CHANNEL SCANLINE COMPUTER CABINET	71	3-CHANNEL I/O EXPANSION CABINET
24	1-CHANNEL VIDEO GENERATOR CABINET	72	3-CHANNEL MAGNETIC TAPE UNIT
25	TERMINAL	73	3-CHANNEL DISK DRIVE
26	3-CHANNEL PRIORITY SECTOR PROCESSOR CABINET	74	3-CHANNEL VIDEO DISPLAY UNIT
		75	3-CHANNEL VIDEO DISPLAY UNIT
27	3-CHANNEL FRAME CALCULATOR CABINET	76	3-CHANNEL HARDCOPY UNIT
28	3-CHANNEL SCANLINE COMPUTER CABINET	77	3-CHANNEL VIDEO GENERATOR CABINET
29	PILOT INSTRUCTOR CONSOLE	78	DIGITAL VOICE DISK DRIVE
30	GUNNER INSTRUCTOR CONSOLE	79-1	PILOT HYDRAULIC PUMPING UNIT
31	1-CHANNEL CPU	79-2	GUNNER HYDRAULIC PUMPING UNIT
32	PILOT BOARDING RAMP	80	VISUAL INTERFACE CABINET
33	GUNNER BOARDING RAMP	81	PILOT COCKPIT DISPLAY INSTALLATION
34	PILOT DISPLAY CONSOLE	82	GUNNER COCKPIT DISPLAY INSTALLATION
35	GUNNER DISPLAY CONSOLE	83 THRU 89	(NOT USED)
36	PILOT ENCLOSURE		
37	GUNNER ENCLOSURE		
38	CPU D	90	TERMINAL (CPU A)
39	CPU E	91	TERMINAL (CPU B)
40	PILOT ENCLOSURE CABINET ASSEMBLY (NOT SHOWN)	92	TERMINAL (CPU C)
		93 THRU 102	(NOT USED)
41	GUNNER ENCLOSURE CABINET ASSEMBLY (NOT SHOWN)		
42	PILOT AIR CONDITIONER	103	1-CHANNEL TEXTURE CABINET
43	GUNNER AIR CONDITIONER	104	3-CHANNEL TEXTURE CABINET
44	(NOT USED)	105	1-CHANNEL MAGNETIC TAPE UNIT
45	3-CHANNEL DISK DRIVE	106	1-CHANNEL LINE PRINTER

Figure 6. Typical UH-60 flight simulator (continued).

Table 1.

Basic, advanced, instrument maneuvers, and emergency procedures that can be performed in the simulator

Ground taxi	Electrical control unit (ECU) lockout operations
Hover power check	Stabilator malfunction
Hovering flight	Emergency procedures (50 active of 341 malfunctions available can be inserted by the IO)
Normal takeoff	Instrument takeoff (ITO)
Maximum performance takeoff	Radio navigation
Traffic pattern flight	Holding instructions
Fuel consumption checks	Unusual attitude recovery
Navigation by pilotage and dead reckoning	Radio communication procedures
Doppler navigation	Two-way radio failure procedures
Before-landing checks	Nonprecision approach
Instrument meteorological condition (IMC) approach	Precision approach
Roll-on landing	Vertical helicopter instrument recovery procedures (VHIRP)
Confined area operations	Masking and unmasking
Slope operations	Tactical communication procedures
Terrain flight takeoff	Electronic counter-countermeasures (ECCM)
Terrain flight	Transmit spot report
Hover out-of-ground-effect (OGE)	Visual meteorological conditions (VMC) approach
Nap-of-earth (NOE) deceleration	Pinnacle ridgeline operation
Terrain flight approach	FM homing
Standard autorotation	Aerial observation
Simulated engine failure at a hover	External load operation
Simulated engine failure at altitude	Internal load operation
Simulated hydraulic system malfunction	Route reconnaissance
Hover, cruise, and landing with degraded automatic flight control system (AFCS)	After-landing tasks
Techniques of movement	
Aircraft survivability equipment operation	
Wire obstacles negotiation	

The simulator compartment houses the cockpit and IO station (Figure 7). Within the cockpit are all the controls, indicators, and panels located in the aircraft. Controls which are not functional are physically present to preserve the appearance of a 100 percent configuration. Loudspeakers are located in the simulator compartment to simulate aural cues.

Each of the pilot's seats are vibrated individually to simulate both continuous and periodic oscillations and vibrations experienced by the crew during normal and emergency flight conditions and maneuvers. However, these vibrations are isolated from the IO and observer stations.

Cooling of the compartment is provided by a single air conditioner outside of the compartment enclosure on the simulator room floor. A thermostat mounted on the right bulkhead in the aft portion of the compartment and a two-speed fan provide control of the inside environment.

The simulator compartment is mounted on a 60-inch six-degree-of-freedom motion system consisting of a moving platform assembly driven and supported from below by six identical hydraulic actuators. The motion system provides pitch, roll, and yaw, lateral, longitudinal, and vertical movement, including combinations of them. Motion of the simulator compartment can be controlled to simulate motion due to pilot inputs as well as those resulting from rotor operation, rough air and wind, and changes in aircraft center-of-gravity, as well as emergency conditions and system malfunctions. All motions except pitch are washed out to the neutral position after the computed accelerations have reached zero. Pitch attitude is maintained as necessary to simulate sustained longitudinal acceleration cues.

The motion system simulates the complex and repeated cues occurring during all the maneuvers associated with the airwork. Turbulence, when used by the instructor-operator, is superimposed on the maneuver being performed with the appropriate effect on yaw and roll, climb and descent, and variations in airspeed. The motion system superimposes all normal periodic oscillations of the aircraft, lateral instability, and aircraft vibration up to 5 cycles per second. The electrohydraulic seat shaker is used to simulate continuous high frequency vibrations while isolating vibration effects from other cockpit-mounted hardware.

Motion can be frozen at any instant and the simulator has the ability to enter a crash override mode where motion can continue despite impact with the ground or other obstacles.

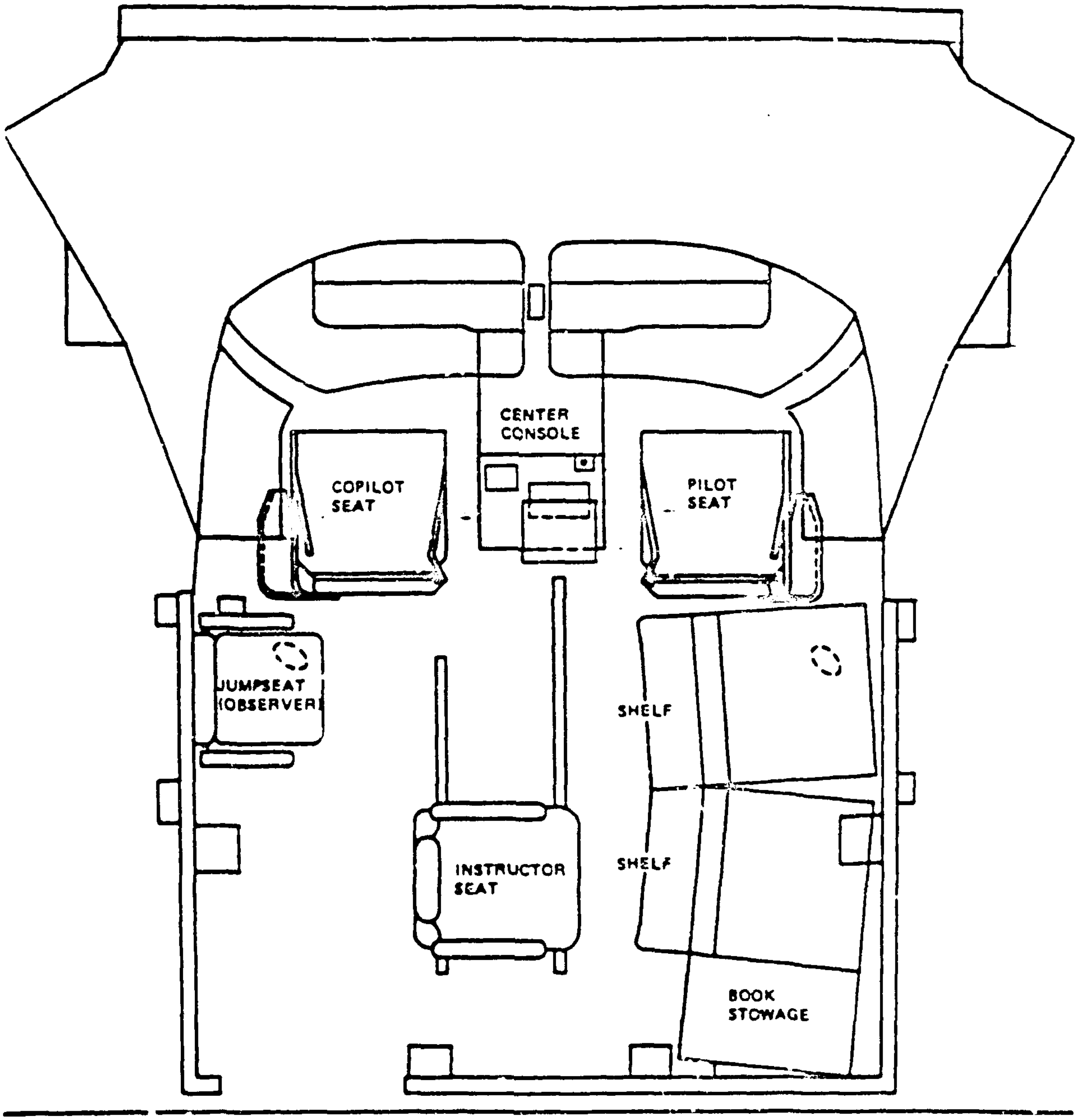


Figure 7. Simulator cockpit and instructor/operator compartment.

The pilot and copilot stations are provided with forward, left, and right side window displays. The visual generation system consists of two separate functional areas. The first is the visual display system (VDS) which presents the wide-angle-collimating video image to the crew. The digital image generator (DIG) system is a full-color visual display that provides imagery for day, night, and dusk scenes as well as replicating the effects of the searchlight/landing light on the visual displays. The instructor-operator must set the eye point in the initial condition setup. This function selects the viewpoint (either pilot's station or copilot's station) to be displayed on the forward displays. This is necessary because they both will display the same image.

The database is a generic European scene of an area 100 by 80 kilometers. The displays are either full color or monochromatic. The monochromatic scene display is designed specifically to be compatible with the use of night vision goggles (NVG). During selection of this mode, the leadship lights are blanked and an exhaust trail is generated from the leadship. The simulator does not input directly to the NVGs except for the out-the-window (OTW) imagery.

The computer system consists of a central processing unit and five auxiliary processing units. The CPU has memory that can be accessed by both itself and the auxiliary processing units. Visual displays are controlled by DIG inputs that are modified by inputs from other units such as the simulator navigation/communication identification subsystem, instructional subsystem, and air vehicle subsystems. The navigation/communication identification subsystem provides position data for the aircraft the simulator is replicating (ownship). The instructional subsystem forwards information that details the visual environment, scene lighting, target paths through the database, target status, and landing light status. The air vehicle subsystem sends information relevant to the ownship position rates, altitude, and attitude. All of these inputs are stored in the shared memory of the main simulator control computer.

The collimating optics used in this simulator are shown in Figure 8. The alignment of the optics in this system produces parallel light rays giving the appearance that the image is at optical infinity. As shown in the diagram at Figure 9, our eyes provide distance measuring information to the brain based partly on the angle between the eyes, or ocular convergence. As objects move closer to the viewer, the eyes must converge in order for both eyes to remain focused on the object. As the object moves further away the angle increases giving the brain data on the distance. Beyond a point approximately 50 feet away from the viewer, the eyes point in virtually parallel directions.

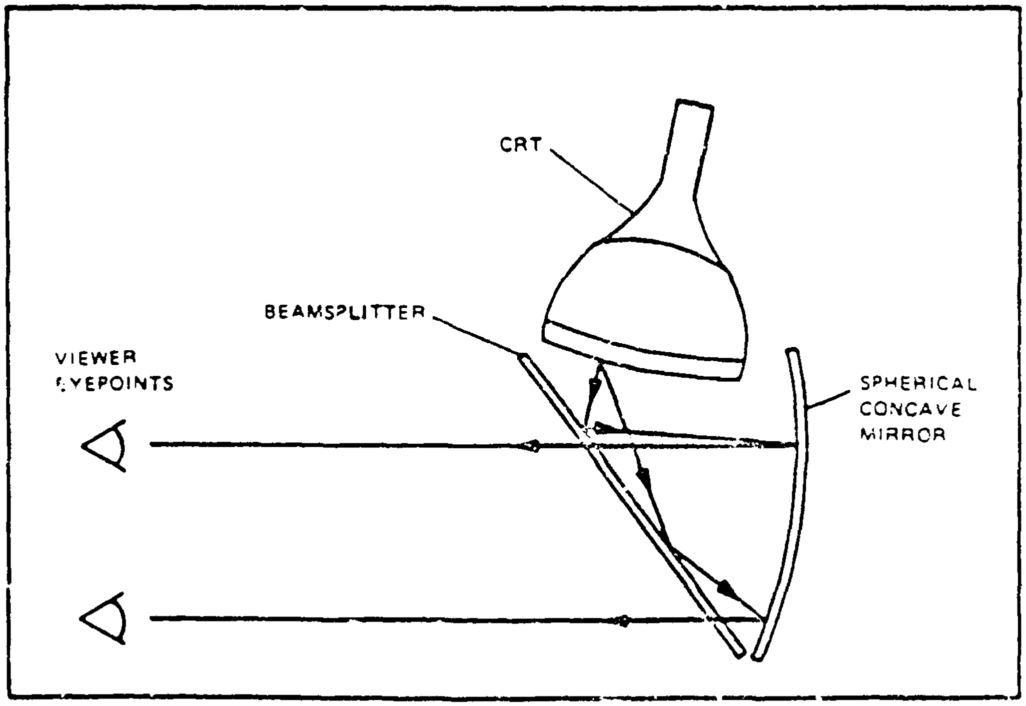


Figure 8. Collimating optics representation.

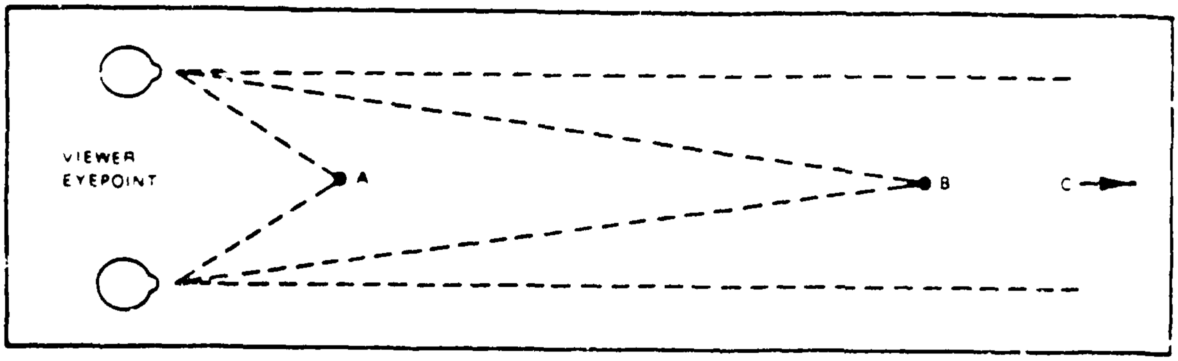


Figure 9. Ocular convergence representation.

In the visual system of the simulator, a spherical mirror is used to effect the collimation of the light rays. When the point source of light is place at a distance equal to one-half the radius of the mirror, rays will enter the mirror and reflect in parallel. Therefore, when the viewer looks at the reflected image, it has the illusion of being quite far away.

There are three main components of the collimating optics in this simulator: The CRT, the spherical concave mirror, and a beam splitter. The beam splitter is necessary to ensure the CRT is out of the line of sight of the pilot. The beam splitter is partially reflective and allows only 50 percent of the light to pass through, the rest is reflected to the mirror. After reflecting off the mirror, the light rays exit through the beam splitter, again lose intensity, and are viewed by the pilot. As a result, the CRT is driven to near its maximum brightness capabilities to compensate for the resulting 82 percent loss of light.

As shown in Figure 10, at any given point on the CRT, the distance from the CRT to the beam splitter to the mirror is one-half the mirror's radius. At the design eyepoint, the rays of light are virtually parallel.

The simulator can operate in three categories: Training, autoflight, and demonstration. In the training mode, the flight is under the control of the instructor-operator who can use numerous capabilities of the simulator to effect the training required. These capabilities include automatic performance recording, automatic demonstrations, numerous malfunctions, as well as other automatic or semiautomatic instructor aids.

In the autoflight mode, a previously recorded demonstration is played back for the trainee. During this re-creation, the simulator flies through an established mission. All motion and aural cues as well as instrument indications, and visual scenes are re-created.

In the demonstration mode, the simulator is used to set up or to edit a demonstration. This includes recording and storing the particular flight in memory, adding commentary, and synchronizing the two in order to effect the demonstration. Fifteen 10-minute demos can be programmed. During this playback of the demonstration, the primary flight controls are positioned and driven by the computer.

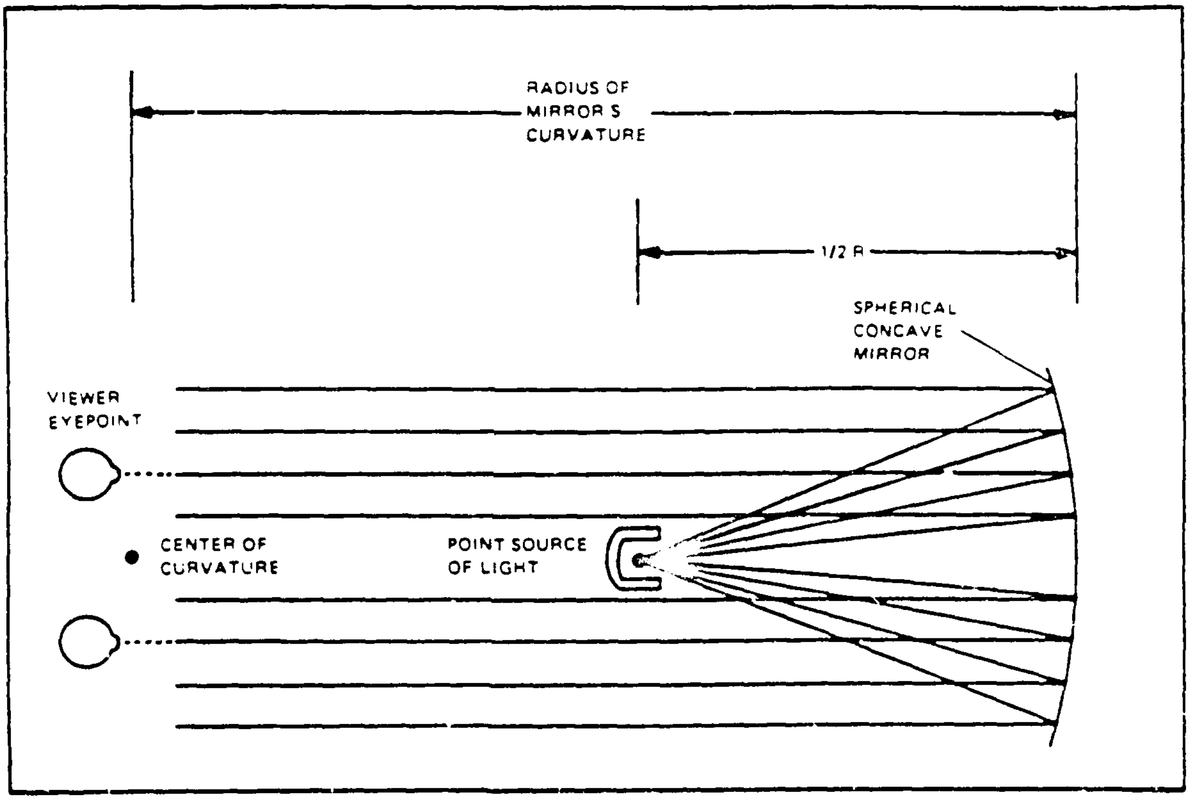


Figure 10. Basic collimation concept.

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 Navy and 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 87 Army aviators surveyed ranged from 21 to 48 years (mean 30.3, SD 6.67). Their ranks ranged from warrant officer 1 (WO1) to chief warrant officer 4 (CW4) and first lieutenant (1LT) to lieutenant colonel (LTC). Flight experience was in the range 150 to 8400 flight hours (mean 1583.48).

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 et al. (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 sub-scales (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 that 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.

The site used was Fort Rucker, Alabama. A target sample size of 100 was the objective, but due to time constraints and the nuances of operational usage of the simulator, only 95 observations were obtained from 87 subjects. They performed the normal program of instruction as prescribed in the UH-60 aircraft qualification course, one of several operations orders (OPORD) designed to maintain proficiency, or other aircrew training manual (ATM) tasks necessary to maintain their proficiency. 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. Difficulty focusing and concentrating also were reported by a substantial number of pilots. 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 convergence 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. The relative prominence of asthenopic and motion sickness symptomatology 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. Incidence of eyestrain in the UH-60 simulator approaches that found in the 2F64C (SH-3H) simulator, the Navy's simulator associated with the highest incidence of simulator sickness. Moreover, incidence of difficulty focusing, headache, and nausea in the UH-60 simulator is the second highest in the sample while incidence of stomach awareness is the highest in the sample. Therefore, it is clear that severity of simulator sickness experienced by pilots training in the UH-60 is well above the average for helicopter simulators.

Table 2.

Percentage* (frequencies) of aircrew reporting postflight symptomatology in the UH-60 simulator. (95 total possible cases)

Asthenopia	Percentage	Motion sickness	Percentage
Eyestrain	34.5 (30/87)	Fatigue	34.9 (22/63)
Blurred vision	9.6 (9/94)	Sweating	20.5 (17/83)
Difficulty focusing	19.1 (17/89)	Nausea	10.7 (10/93)
Difficulty concentrating	14.9 (13/87)	Dizziness (eyes closed)	5.3 (5/94)
Headache	22.2 (20/90)	Dizziness (eyes open)	3.2 (3/95)
		Vertigo	3.2 (3/95)
		Salivation increase	4.5 (4/89)
		Stomach awareness	15.7 (14/89)
		Fullness of the head	7.6 (7/92)

* 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:	2B38	2B40	2B42	SH3H	CH46E	CH53D	CH53E
Aircraft:	UH-60	AH-64	TH-57C	2F64C	2F117	2F121	2F120
Asthenopia							
Eyestrain	35	24	27	37	16	21	23
Difficulty focus	19	6	7	24	6	6	10
Headache	22	14	7	31	12	9	17
Motion sickness							
Nausea	11	6	5	15	9	8	11
Dizzy, eyes open	3	1	4	9	3	1	[illegible]
Stomach awareness	16	5	1	14	7	2	4
Vertigo	3	1	3	10	3	1	4
Observations:	95	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 simulator sickness questionnaire (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 aviators who train in the UH-60 simulator experience a marked change in symptomatology over the course of a training session.

Table 4.

Pre- and post SSQ means (standard deviations) and paired t-test values (95 observations).

SSQ scale	Pre	Post	Difference Mean	t	p
Nausea	105.0 (8.7)	113.0 (18.0)	7.93	4.20	.000
Visuomotor	106.1 (10.1)	117.1 (17.1)	11.01	6.77	.000
Disorientation	101.9 (6.3)	109.7 (17.1)	7.77	4.75	.000
Total severity	105.5 (8.7)	116.1 (17.3)	10.63	6.44	.000

Figures 11 through 14 show the severity of postflight SSQ scores 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 11 through 14. It can be seen that the severity of postflight symptomatology on each of the SSQ scales for the UH-60 simulator is the second highest in the sample, substantiating the data for individual symptoms shown in Tables 2 and 3. 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 UH-60 clearly meets this criterion on each subscale and on the total severity scale, implicating perhaps both the visual and motion base systems in contributing to symptomatology.

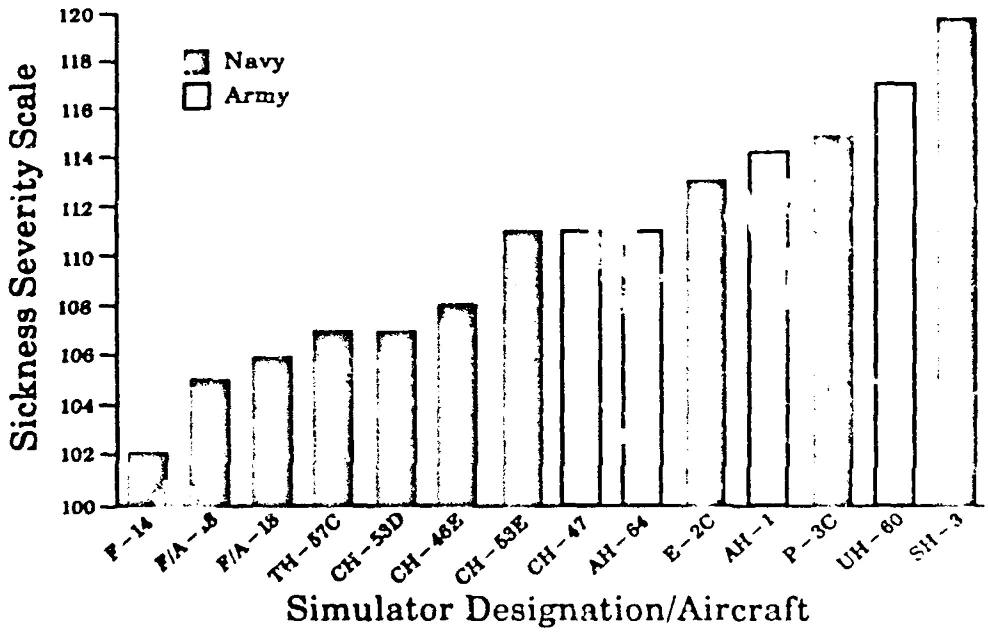


Figure 11. SSQ visuomotor subscale.

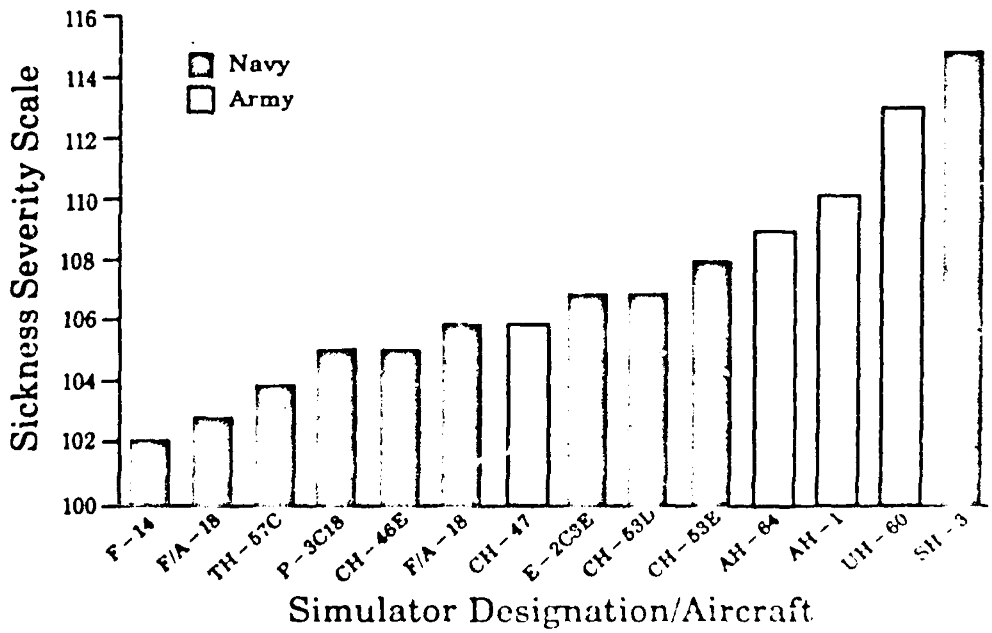


Figure 12. SSQ nausea subscale.

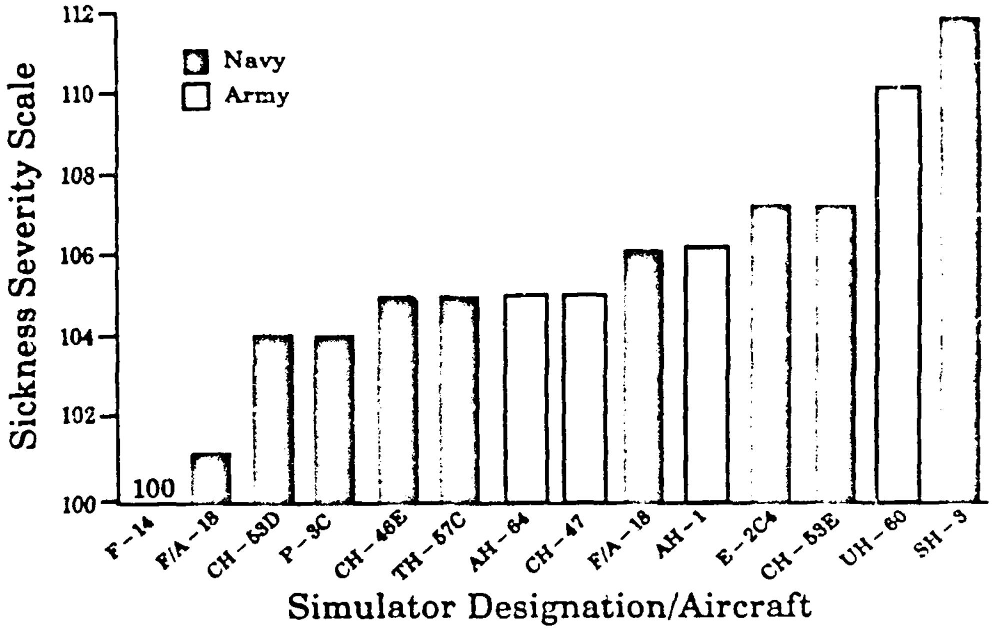


Figure 13. SSQ disorientation subscale.

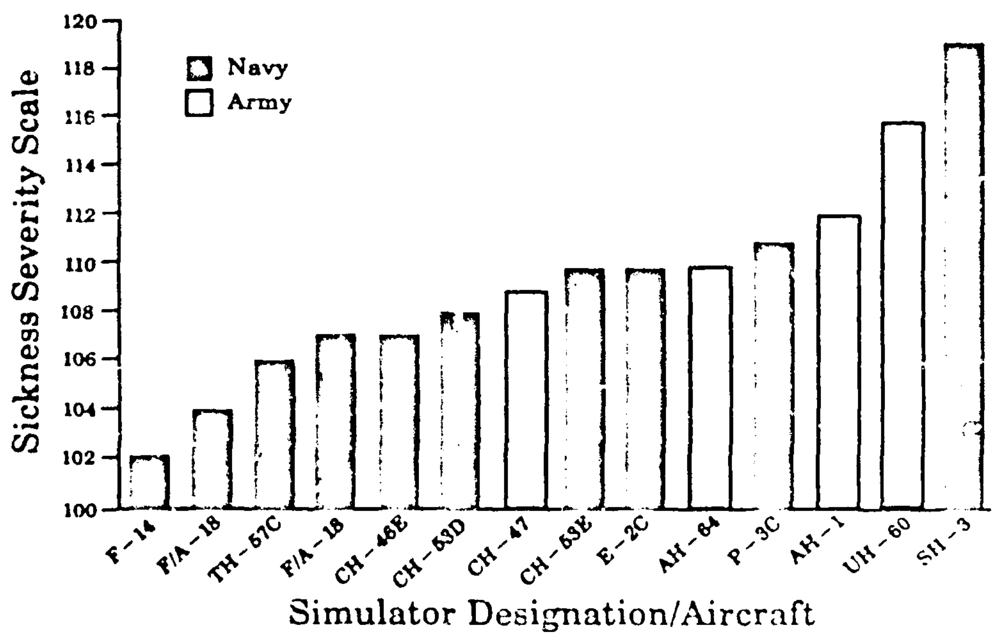


Figure 14. SSQ total severity score.

Postural stability

Postural equilibrium test (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 statistically reliable changes on any of the PET tests. These results appear to suggest pilots who train in the UH-60 simulator are not at risk for postural disturbances. However, this may be an erroneous conclusion in light of (1) the severe symptomatology experienced by aircrew training in the UH-60 simulator, and (2) evidence presented in Table 6 which suggests pilots who experience symptomatology are likely to experience disruption on the SONLEC test. Furthermore, due to time constraints placed upon the researchers on site, none of the pilots had sufficient practice on any of the tests to reach proficiency. Therefore, learning may be taking place during the testing, thus giving a false picture of the pilot's true postural stability.

Table 5.

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

	WOFEC		SONLEC		SOPLEC	
	Pre	Post	Pre	Post	Pre	Post
Mean	11.59	11.72	26.56	26.38	26.74	26.66
SD	1.09	.92	5.98	6.55	6.21	7.31
Min-max	4.7-12	6.3-12	5.0-30	7.6-30	4.3-30	
4.3-30						
t(df), p value	*t*(90)= -1.01	*p*=.31	*t*(90)= .38	*p*=.707	*t*(90)= .15	*p*=.879
Observations	91	91	91	91	91	91

Correlations

Table 6 shows correlations of 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 A. Only correlations that reached the .05 level of statistical significance were presented in the table.

Table 6.

Intercorrelations among variables.
(95 total possible observations)

	SSQ scores			
Pilot variables	N	V	D	TS
Rotary-wing hours	.23		.24	
Recent flight hours			.24	
Days since last simulator flight			.29	
Sleep	-.21	-.18	-.25	-.24
Enough sleep	.31	.36	.25	.37
MHQ	.33	.28	.24	.34
Simulator sickness	.23	.19	.20	.24
SONLEC	.26		.20	.21
Simulator variables				
Seat shaker on/off	-.24	-.28	-.19	-.29
Collective		.19		
Pitch		.27		
Roll		.30	.21	.22
Torque		.36		.22
Percent NOE		-.19		
Percent upper air			.21	
Night		.25		
Landings attempted		.21		
Visual traits		-.27		
Motion disruptions		-.17		
Training variables				
Different from aircraft	.33	.40	.38	.43
Discomfort hamper training		.43	.43	.44

Pilot variables

Greater total and recent flight hours were associated with higher SSQ scores, a finding reported in previous surveys (McGuinness, Bouwman, and Forbes, 1981) that suggests pilots with more flight experience are at more risk for simulator sickness. The greater number of days since the last flight in the UH-60 simulator, the more severe the symptomatology experienced. This finding would be expected: that is, if an aircrew are adapting to the provocative aspects of the simulation, then many days between simulation flights would tend to disrupt the learning process. Inadequate sleep was associated with higher symptomatology scores, in keeping with the view that pilots who are not in their usual state of fitness may be more susceptible to simulator sickness. Sixteen percent of the sample rated their previous night's sleep as "not enough." Pilots' ratings of whether they got enough sleep was related to symptomatology, suggesting this may be an easily obtained and useful predictor variable. Two other predictor variables also were identified: MHQ scores and whether simulator sickness has occurred in the past were both predictive of SSQ scores.

Finally, SONLEC scores positively were related to simulator sickness severity suggesting that aviators who experience the worst symptomatology are more at risk for postural disturbances.

Simulator variables

Correlations between "seat shaker" and SSQ scores suggests the seat shaker may contribute to symptomatology. In postflight interviews, aircrews noted symptomatology was more severe with the seat shaker on. Some referred to the seat shaker as a "vibrator that rattled their teeth."

Variables related to aircraft control ("collective, pitch, roll, and torque") suggest the worse the aircrew rated the controls, the more severe the symptomatology. Implicated from this finding are throughput delays and visual-motion lags in the simulator as possibly contributing to symptomatology.

Interestingly, the greater the percentage of NOE flight, the lower the symptomatology, while the opposite was true for percentage of upper air work. On other scenario content variables, training under the night flying condition was associated with increased symptomatology, probably because it was associated with NVG training. In addition, greater number of landings was associated with increased severity of sickness, which may be due to the increase in near ground interaction which is thought to be nauseogenic (Kennedy et al., 1987a). Finally, noted visual traits that need correcting and noted disruptions in the motion system were associated with more severe symptomatology.

There was an inadequate distribution of the "motion system on/off" variable to calculate a correlation (only one flight was conducted with the motion system off). 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 had experienced in the actual aircraft. This is evidence simulator sickness symptomatology is more severe than symptomatology experienced in the actual aircraft.

Also, it can be seen that greater symptomatology is 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 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	57	66.3
Tend to disagree	15	17.4
Neutral	13	15.1
Tend to agree	1	1.2
Strongly agree	0	0.0
Observations	86	

Symptomatology by mission and seat

Mission

Table 8 shows SSQ scores broken out by mission type: Proficiency, instruments, and NVG. Overall, UH-60 aircrews undergoing proficiency training reported the most severe symptomatology. Proficiency training represents a variety of training scenarios. It can be seen in Table 9, showing key scenario content variables for the mission types, there tended to be greater variability within this mission category.

Table 8.

SSQ scores by mission (means and standard deviations).

SSQ scale	Proficiency	Instrument	NVG
Nausea	117.1 (20.3)	109.9 (13.6)	107.2 (7.4)
Visuomotor	116.5 (15.4)	114.9 (18.9)	125.0 (17.6)
Disorientation	112.0 (17.7)	106.1 (14.5)	107.8 (17.6)
Total severity	118.1 (17.1)	112.9 (16.8)	117.1 (14.6)
Observations	44	25	16

Table 9.

Scenario content data (means and standard deviations) for different missions flown in the UH-60 simulator.

	Mission		
	Proficiency	Instrument	NVG
Percent NOE	2.5 (7.4)	0.6 (3.1)	1.6 (5.1)
Percent upper air	31.5 (34.2)	3.4 (7.0)	24.9 (27.6)
Landings attempted	3.5 (2.6)	4.5 (6.9)	4.4 (4.5)
Observations	44	25	16

NVG training resulted in extremely high scores on the SSQ visuomotor subscale. Comments from the aviators revealed many of them felt marked disdain for training with NVGs in the UH-60 simulator. In addition, 9 of the 16 aviators who flew NVG missions rated their symptoms as worse than those they experienced when using NVGs in the actual aircraft. Use of NVGs per se may result in eyestrain, and, when coupled with use in a simulator that originally was not designed for NVG training, can be expected to cause severe asthenopic symptoms.

Seat

SSQ scores are broken out by seat in Table 10. Comparisons of severity of simulator sickness for pilots, copilots, and for aircrew training in both seats show that aircrew training in the copilot's seat and in both seats are at most risk for simulator sickness. A comparison of missions flown for the seat categories (Table 11) shows although they are comparable in terms of number of NVG missions flown, there were more proficiency missions flown by pilots in the copilot's and in both seats. In addition, other key scenario variables (from Table 6) could contribute to the difference; aircrew training in the copilot and in both seats spent, on average, a greater percentage of the time in upper air work, shown in Table 6 to be provocative.

Table 10.

SSQ scores by seat (means and standard deviations).

	Seat			
SSQ scale	CP	Pilot	CP/P	IO
Nausea	115.9 (17.0)	107.2 (13.9)	114.6 (17.5)	113.9 (26.3)
Visuomotor	119.6 (16.0)	113.9 (17.1)	117.6 (18.0)	116.9 (18.1)
Disorientation	111.6 (20.0)	108.1 (16.9)	107.8 (15.0)	113.9 (18.0)
Total severity	119.0 (17.5)	111.8 (17.5)	116.5 (15.7)	117.6 (21.1)
Observations	24	24	34	13

There were 13 observations of instructor operators. These data suggest, under the conditions of the simulation flights flown by these individuals, instructor operators are at risk for simulator sickness. In addition, experimenter interviews with instructor operators revealed that symptomatology experienced after several periods in the simulator may be particularly severe.

Table 11.

Mission and scenario content data for copilot and pilots

	Seat		
	CP	Pilot	CP/P
Percent aircrew flying key missions:			
Proficiency	54.2	37.5	58.8
Instruments	20.8	25.0	20.6
NVG	20.8	20.8	17.6
Means (standard deviations) for key scenario variables:			
Percent NOE	1.25 (5.16)	5.00 (12.3)	3.53 (15.1)
Percent upper air	23.96 (30.9)	10.70 (17.7)	30.76 (35.1)
Landings attempted	3.63 (3.4)	4.42 (5.6)	3.88 (3.0)
Observations	24	24	34

Discussion

The principal goal in this field study was to assess the incidence of simulator sickness in the UH-60 flight simulator. The results show training in this simulator produces a higher incidence of simulator sickness than the three other Army visually coupled flight simulators, the AH-1, the CH-47, and the AH-64. As in other systems, eyestrain and headache were leading symptoms of asthenopia, while fatigue and sweating were leading symptoms associated with motion sickness. The high scores on the N, V, D, and TS SSQ scales ranks the UH-60 as one of the two worst simulators for simulator sickness studied by the Army and the Navy.

The high scores are cause for concern and raise questions about the visual and motion base representation of flight experienced by the aviators in the UH-60 flight simulator. The tasks accomplished in this simulator require close coordination between the pilot and the copilot that should not be degraded because of the general discomfort of the aircrew due to simulator effects. The fact that copilots showed higher scores than pilots raises concern for the design of the visual representation of information from the other aviators viewpoint as is done in the UH-60. Of further concern to us is the relatively high scores on the SSQ scales seen for aircrews flying instrument flight which are relatively benign scenarios. This time spent with no scene content should produce lower SSQ scores. If, in fact, the aviators are having problems with the simulator flying under instrument conditions, then there is cause for concern.

The use of NVGs in the UH-60 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 (POIs) 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 is 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. In fact, time was very limited during this study to the point that some had little or no practice whatsoever. It is possible the lack of significant decrements on any of the three tests is 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 more sensitive standing- and walking-based tests or stabilimeter measurement should be considered.

Recent anecdotal information received at USAARL from fielded UH-60 flight simulator sites has indicated aviators flying regular missions in the UH-60 flight simulator have experienced delayed effects beyond the simulator flight itself. Some were reported to have occurred over 24 hours postexposure. This report was not able to assess the time course of the postflight symptomatology; however, the relative degree of severity and reports of other delayed symptoms is cause for a further look at the issue.

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. This also should include adherence to the 6-hour waiting period advocated in USAARL 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 experiences delayed problems beyond the simulator exposure and for periods that exceed 6 to 8 hours for approximately 8 percent of the population and 1-to-2 days for an even smaller population.

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 that 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 device 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., Allgood, G. O., Lilienthal, M. G., and Gower, D. W. 1987. Flashbacks and other delayed effects of simulator sickness: Incidence and implications. Unpublished manuscript.

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. Washington, D.C. Military Standard 1472C.

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

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

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 SAE 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. Orlando, FL: Naval Training Systems Center. NTSC-TR-87-007.

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., and Graybiel, A. 1965. The dial test: A standardized procedure for the experimental production of canal sickness symptomatology in a rotating environment. Pensacola, FL: Naval School of Aerospace Medicine. Report No. 113, NSAM 930.

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). Orlando, FL: Essex Corporation. EOTR 88-7.

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

Link Flight Simulation Corporation. 1988. Operation and maintenance, organizational and intermediate levels, UH-60 (Black Hawk) flight simulator, visual display. Link Flight Simulation Corporation, 15 August 1988. TM-55-6930-217-23-3.

Link Flight Simulation Corporation. 1988. Operator's manual for the UH-60 flight simulator. Link Flight Simulation Corporation, 15 March 1988. TM 55-6930-217-10.

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

McGuinness, J. Bouwman, J. H., and Forbes, J. M. 1981. Simulator sickness occurrences in the 2E6 air combat maneuvering simulator (AMCS). Orlando, FL: Naval Training Equipment Center. NAVTRAEQUIPCEN 80-C-0135-4500-1.

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 Karkowski, W. (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.

Operator's Manual. 8 January 1987. UH-60A and EH-60A helicopter. Headquarters, Department of the Army. TM 55-1570-237-10.

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.

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 [illegible] week?

   No ____ Yes ____ If "Yes," explain ________________________________

   ____

Serial No. ____________ Date ______________

9. When you were nauseated <u>for any reason</u> (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 got 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. 95% 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? ___

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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

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7

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
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________				

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.

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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 .

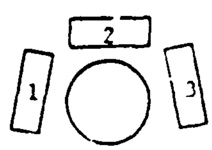
4b. The cyclic pitch control was: EXCELLENT/ GOOD/ FAIR/ BAD .

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 ______

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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:

____

____

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Appendix B.

Variable descriptions

Variable	Description	Code
Pilot variables		
Rotary-wing hours	Total flight hours in rotary-wing aircraft	Number of hours
Recent flight hours	Flight hours in last 2 months	Number of hours
Days since last flight	Number of days since last flight in the aircraft	Number of days
Sleep	Hours sleep previous night	Hours sleep
Enough sleep	Was the amount of sleep previous night sufficient?	1=Yes, 2=No
MHQ	Motion history questionnaire susceptibility score	Range: 0 to 5 0 = low susceptibility
Simulator sickness	Have you ever experienced simulator sickness?	1=Yes, 0=No
SONLEC/SOPLEC	Pre- minus post score	
Simulator variables		
Seat shaker on/off	Seat shaker on or off during flight	1=On 2=Off/Degraded
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
Roll Control	How was the roll control?	1=Excellent 2=Good 3=Fair, 4=Bad

Simulator variables	Description	Code
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
Percent upper air	Percent of flight spent in upper air work	Percentage
Night	Night flight conditions	1=Yes, 0=No
Landings attempted	Number of landings attempted	Number of landings
Visual traits	Are there bothersome visual traits that need correcting?	1=Yes, 2=No
Motion disruptions	Notice any disruptive motion system problems?	1=Yes, 2=No
Training variables		
Different from aircraft	Are symptoms experienced the same or worse than those experienced in the actual aircraft.	1=Same, 2=Worse
Discomfort hampers 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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