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PRELIMINARY AIRWORTHINESS EVALUATION OF A UH-1 EQUIPPED WITH A TERRAIN MAPPING RECEIVER ANTENNA

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FINAL REPORT

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US ARMY AVIATION ENGINEERING FLIGHT ACTIVITY
EDWARDS AIR FORCE BASE, CALIFORNIA 93523 - 5000

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The preliminary airworthiness evaluation of the UH-1H helicopter equipped with the receiver antenna of the Terrain Mapping Radar System was conducted in Lakehurst, New Jersey, between 21 November and 8 December 1986. The evaluation required 12 flights for a total of 14.8 hours, of which 12.0 hours were productive. Performance, handling qualities, and structural dynamic response tests were conducted. The modified UH-1H equipped with the receiver antenna demonstrated adequate handling qualities for the terrain mapping mission. However, the proposed mission profile requires extensive operation of the helicopter in an out-of-ground effect (OGE) hover. Although the handling qualities are acceptable, the degraded autorotational characteristics may preclude a safe autorotational landing in the event of a sudden engine failure at an OGE hover below 1000 feet above ground level. The minimum directional control margin and high pilot workload required to maintain heading during low speed flight were a shortcoming. Three additional shortcomings were found during the evaluation.

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INTRODUCTION

BACKGROUND

1. The US Air Force contracted for Calspan Corporation and the US Army Communications and Electronics Command (CECOM) to develop and install a terrain mapping radar system into two UH-1H helicopters. One helicopter was equipped with an internally mounted transmit antenna. The second helicopter was equipped with a large (48-inch diameter), dish-like receiver antenna which was attached to the outside of the helicopter at the right-hand cargo door location. The mission profile of the helicopter with the receiver antenna requires extensive out-of-ground effect (OGE) hover. The US Army Aviation Systems Command (AVSCOM) monitored the electrical and structural modifications necessary to install the receiver antenna into the UH-1H helicopter. The AVSCOM Test Request (ref 1, app A) tasked the US Army Aviation Engineering Flight Activity (AEFA) to conduct a Preliminary Airworthiness Evaluation (PAE) of the UH-1H helicopter modified for the receiver antenna in accordance with the approved test plan (ref 2, app A).

TEST OBJECTIVE

2. The objective of the test was to determine the handling qualities and performance of the UH-1H helicopter modified for the terrain mapping receiver antenna within a restricted flight envelope.

DESCRIPTION

3. The test helicopter was a production UH-1H, S/N 66-0894. A detailed description of the UH-1H is contained in the operator's manual (ref 3, app A). The UH-1H was modified to incorporate the receiver antenna of the terrain mapping radar system and associated electronic equipment racks mounted in the cabin area (photos 1 and 2). The receiver antenna was a 48-inch diameter radar dish suspended from the right-hand side of the helicopter by a single cantilever beam attached to the transmission support structure. The receiver antenna was attached to the cantilever beam via a yoke assembly which allowed movement of the antenna in azimuth, elevation, pitch, and roll (photo 3). The right cargo door and a section of the helicopter roof above the right cargo door were removed to accommodate antenna installation and movement (photo 4). The crew compartment was separated from the antenna area by a removable sheet metal panel which contained a plexiglass window (photo 5). An onboard operator controlled the gyro-stabilized receiver antenna through computer controlled

Photo 1. UH-1H Helicopter Equipped with Terrain Mapping Receiver Antenna (Secured Antenna Configuration)

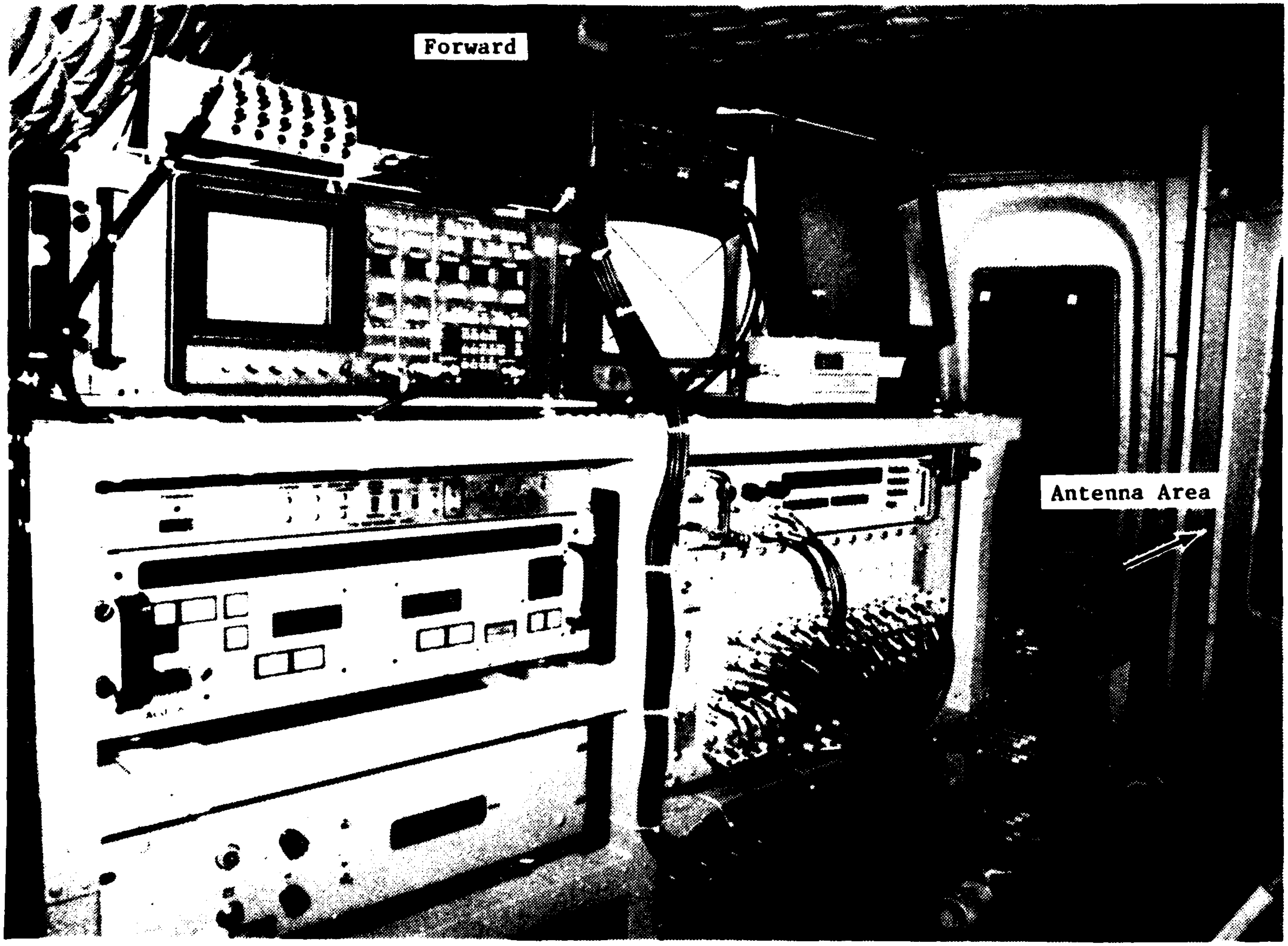

Photo 2. Electronic Equipment at the Operator's Station

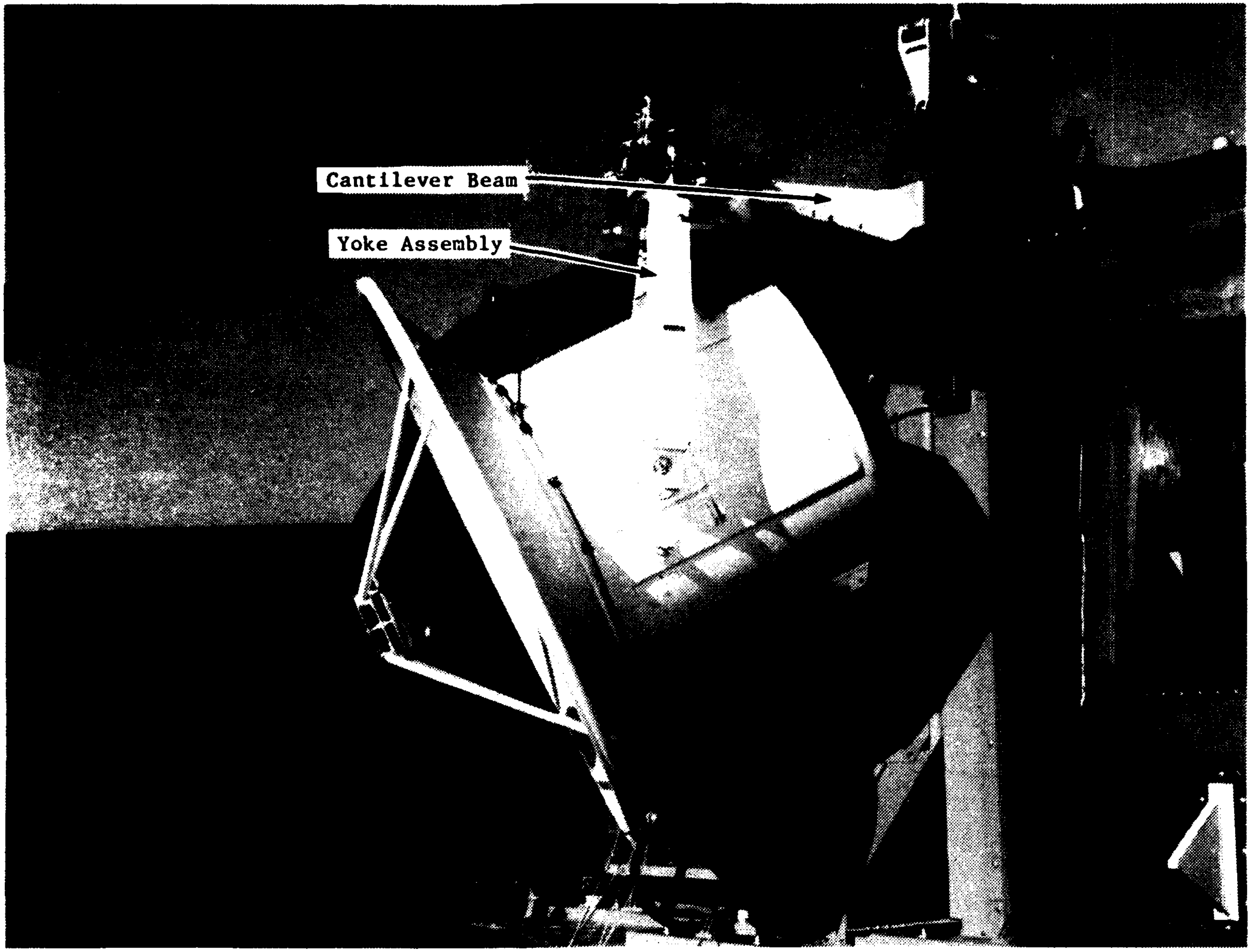

Photo 3. Receiver Antenna Full Aft and Down
(Operational Antenna Configuration)

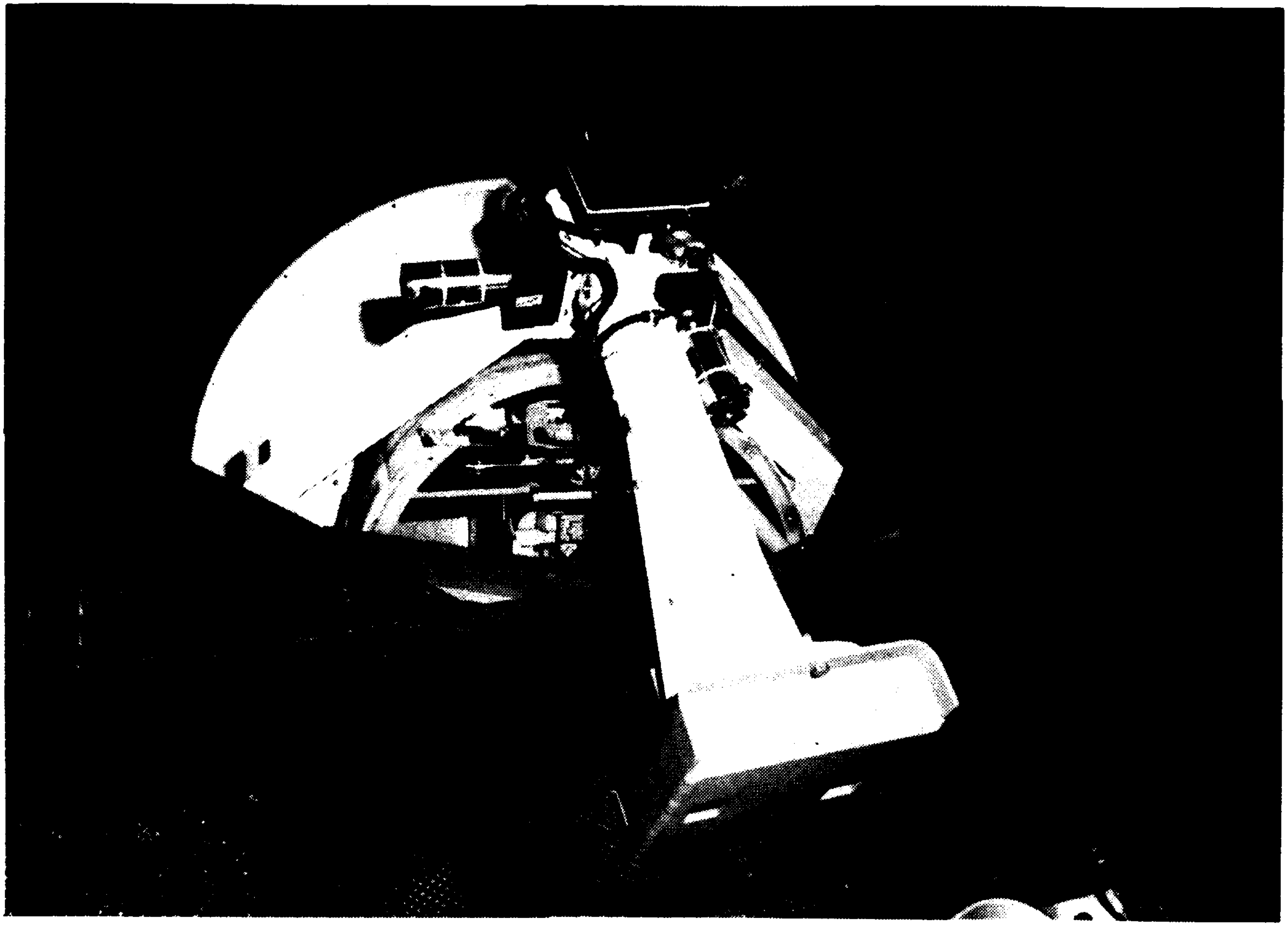

Photo 4. Helicopter Roof Modification

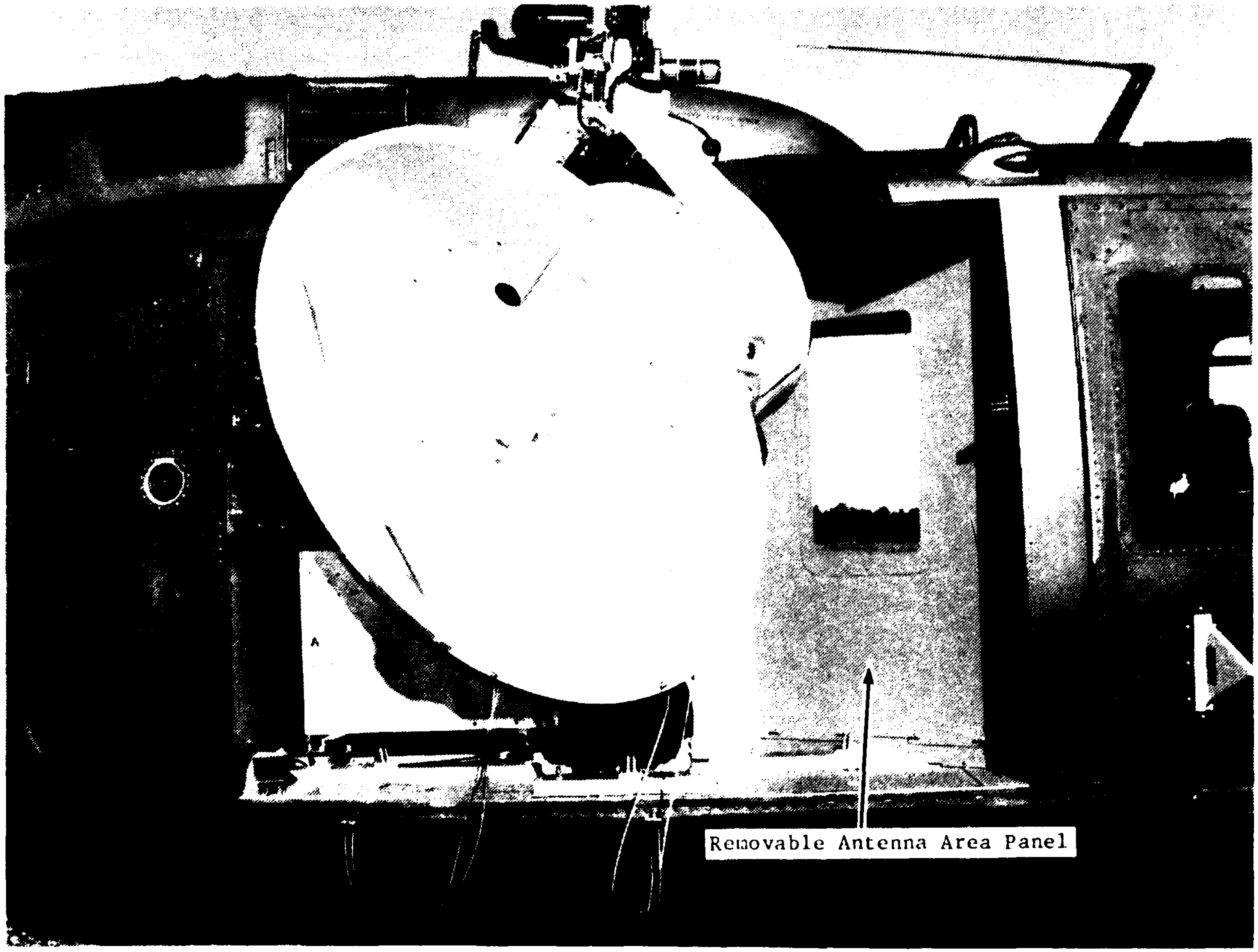

Photo 5. Receiver Antenna Full Aft and Down
(Operational Antenna Configuration)

servo motors which positioned the antenna within the full range of motion (+10 deg to -18 deg elevation and ±26 deg azimuth) while at a hover. When electrical power is removed from the servo motors, the antenna is free to rotate about any axis. Consequently, the receiver antenna was designed to be mechanically secured to the helicopter with four support tubes when in transit to and from the operational area. A full description of the terrain mapping radar system is contained in the pamphlet "Four Axis Gimbal System Transmitting Model 5550-85 Receiving Model 5050-85" (ref 4). The receiver antenna, yoke assembly, and cantilever beam may be removed for ferry flights, leaving only the vertical support structure and antenna electrical components mounted in the antenna area (photos 6 and 7).

TEST SCOPE

4. The evaluation was conducted at the Lakehurst, New Jersey Naval Aviation Engineering Center (NAEC) (elevation 103 feet). A total of 14.8 flight hours were flown in 12 flights between 21 November and 8 December 1986, of which 12.0 hours were productive. The test aircraft was provided, maintained, and configured by CECOM at NAEC. Calspan Corporation provided equipment operators for tests requiring antenna operation. The aircraft was tested in the configurations presented in table 1 at the conditions presented in table 2. Testing was conducted in accordance with the test plan (ref 2) and within the constraints of the UH-1H operator's manual (ref 3) and the airworthiness release (ref 5).

TEST METHODOLOGY

5. Flight test data were manually recorded from standard UH-1H helicopter flight instruments and cloth measuring tapes affixed to the copilot cyclic and pedals. Established flight test techniques were used (refs 6 and 7) and are discussed in appendix B. A Handling Qualities Rating Scale (HQRS) (fig. 1, app B) was used to augment pilot comments relative to handling qualities. A Vibrations Rating Scale (VRS) (fig. 2) was used to augment pilot comments relative to vibration. Pilot comments were recorded on cockpit data cards and an onboard voice recorder.

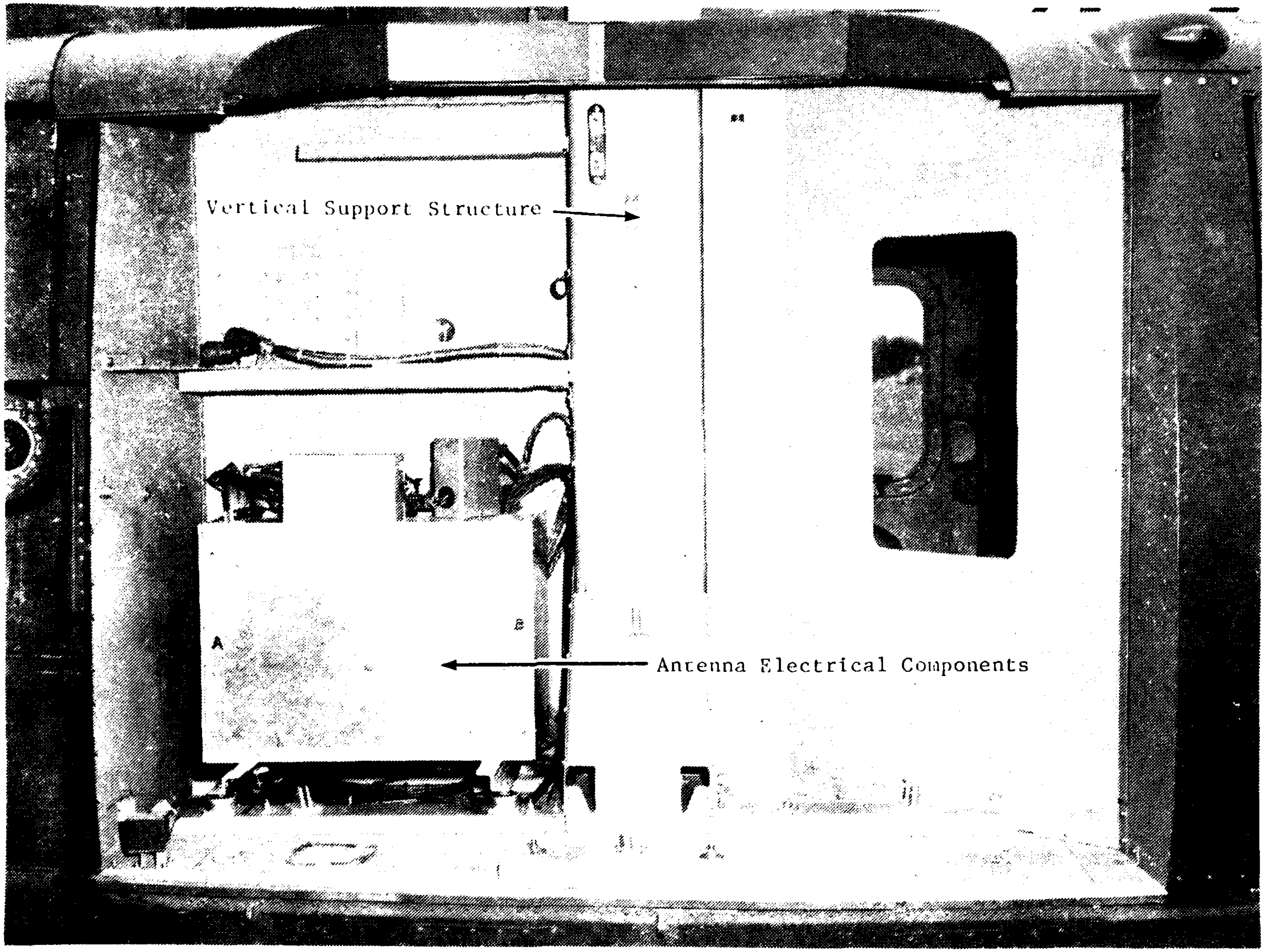

Photo 6. Antenna Area (Ferry Configuration)

Photo 7. Modified UH-1H Helicopter (Ferry Configuration)

Table 1. Antenna Test Configuration

Configuration	Terrain Mapping Receiver Antenna
Ferry	Antenna removed, support structure installed
Secured	Antenna installed and mechanically safetied
Operational	Antenna installed and operating

Table 2. Test Conditions[1]

Test	Average Gross Weight (lb)	Average Density Altitude (ft)	Trim Airspeed (KIAS)[2]	Antenna Configuration	Remarks
Autorotational Descent Performance	8200	5000	40 to 60	Secured	Ball-centered, engine operating at flight idle
Flare Performance			60		
Static Longitudinal Stability	8360	5000	50	Secured	Level flight
	8200				Climb and autorotation
Static Lateral-Directional Stability	8200	5000	50	Secured	Level flight and climbs
			60		Autorotations
Dynamic Stability	8200	-1000	0	Secured	OGE[3] hover
		5000	50		Level flight
Low Speed Flight Characteristics	8190	-1900	0 to 30 KTAS[4]	Secured	0, 45, 90, 270 degree relative azimuths, left cargo door open with antenna area panel removed and left cargo door closed with antenna area panel secured. 135 and 180 degree relative azimuths door closed, panel secured
	8390	-1400		Operational	45 degree relative azimuth with antenna manually operated
Effects of Antenna Operation	8390	-1000	0	Operational	Winds 15 to 20 knots
Simulated Engine Failure	8200	5000	0, 60	Secured	Simulated by reducing throttle to flight idle position. Level flight and MRP[5] climb.
Simulated Electrical Failure of Mission Equipment		-1000	0	Operational	Winds 15 to 20 knots
Structural Dynamics	8300	4000	0 to 60	Secured	Level, climbing, descending, hovering flight
	8200		0 to 90	Ferry	

NOTES:

[1]All tests were conducted at a mid average longitudinal cg (135.6 to 136.2)
[2]KIAS: Knots indicated airspeed.
[3]OGE: Out-of-ground effect.
[4]KTAS: Knots true airspeed.
[5]MRP: Maximum rated power.

RESULTS AND DISCUSSION

GENERAL

6. The modified UH-1H helicopter equipped with the receiver antenna demonstrated adequate handling qualities for the terrain mapping mission. Handling qualities were changed from the standard UH-1H helicopter but were acceptable. However, the proposed mission profile requires extensive operation of the helicopter in an OGE hover. The degraded autorotational characteristics may preclude a safe autorotational landing in the event of a sudden engine failure at an OGE hover below 1000 feet above ground level (AGL). The degraded autorotational characteristics were attributable to the increased autorotational rate of descent, the short collective reaction delay time available following a sudden engine failure, and the minimum descent airspeed of 60 knots indicated airspeed (KIAS) which was velocity-never exceed (V_{NE}) and difficult to maintain. Additionally, four shortcomings were identified.

PERFORMANCE

Autorotational Descent Performance

7. The autorotational descent performance of the UH-1H equipped with the terrain mapping receiver antenna was evaluated at the conditions listed in table 2. Additional tests were conducted in the ferry configuration for comparison. A coordinated entry technique was used and steady state autorotation was established at 324 rotor rpm. The results of the test are presented in table 3.

Table 3. Autorotational Descent Performance

Knots Indicated Airspeed	Rate of Descent (fpm)
Antenna Secured	
40	2050
50	2000
60	1950
Ferry	
60	1800
90	2200

At the airspeed for minimum rate of descent (60 KIAS) which was the established V_{NE} the UH-1H equipped with the receiver antenna demonstrated an 8 percent (approximately 150 fpm) increased rate of descent compared with a standard UH-1H (ref 3). The right pedal margin remaining in steady state autorotation was 15 percent at 60 KIAS. In the ferry configuration, the autorotational descent performance corresponded to the performance presented in the UH-1H operator's manual. The following note should be included in the airworthiness release for the modified UH-1H helicopter.

NOTE

> Higher rates of descent than predicted in the operator's manual (approximately 150 fpm greater at 60 KIAS) can be expected during autorotation in the UH-1H equipped with the terrain mapping receiver antenna.

Flare Performance

8. Flare performance was qualitatively evaluated from steady state autorotational entry airspeed of 60 KIAS at 5000 ft density altitude. Constant rate flares of 5 through 20 degrees of pitch attitude change were performed in 5 degree increments. Flares of 10 to 20 degrees pitch attitude change resulted in a rotor speed increase of approximately 10 rpm and a decreased rate of descent.

HANDLING QUALITIES

Static Longitudinal Stability

9. The static longitudinal stability characteristics of the UH-1H helicopter equipped with the terrain mapping receiver antenna were evaluated during level flight, maximum power climbs, and autorotations at the conditions presented in table 2. Data for level flight are presented in figure 1, appendix C. In level flight, the longitudinal control position versus airspeed gradient indicated neutral static longitudinal stability. During maximum power climbs, the longitudinal control position versus airspeed gradient indicated weak, but positive static longitudinal stability. The longitudinal control position versus airspeed gradient during autorotational descent indicated weak, but positive static stability for airspeeds greater than trim airspeed, and neutral to negative static stability for airspeeds less than trim airspeed. Pitch attitude changes were small for all off-trim airspeed conditions (± 2 deg from trim attitude). Longitudinal cyclic position and force cues to off-trim conditions were

weak. The poor position and force cues, and the small attitude changes with off-trim conditions required constant monitoring of the airspeed indicator to maintain trim airspeed to prevent exceeding the V_{NE} of 60 KIAS. The neutral static longitudinal stability near V_{NE} (60 KIAS) is a shortcoming.

Static Lateral-Directional Stability

10. The static lateral-directional stability characteristics of the UH-1H equipped with the terrain mapping receiver antenna were evaluated during level flight, maximum power climbs, and autorotations at the conditions presented in table 2. Data are presented in figure 2, appendix C. Directional stability was positive about trim (increasing left pedal required for increasing right sideslip) for all conditions tested. Right sideslips beyond 1/2 ball width resulted in near neutral directional static stability. Effective dihedral was positive (increasing right cyclic required for increasing right sideslip) during level flight and maximum power climbs. However, the effective dihedral was asymmetric, being stronger in right sideslips than left sideslips. During autorotations, the effective dihedral was neutral in left sideslips and slightly positive in right sideslips. Side force characteristics (change in roll attitude with sideslip) were positive in left sideslips, but neutral in right sideslips. The static lateral-directional stability characteristics of a standard UH-1H helicopter were significantly different, being positive with both left and right sideslips as reported in the YUH-1H Final Report (ref 8). The asymmetric sideforce characteristics were annoying and required the pilot to check visually the trim ball for out-of-trim indications. Consequently, with asymmetric effective dihedral and sideforce characteristics the pilot will have poor cues to an out-of-trim condition. The asymmetric static lateral-directional stability characteristics are a shortcoming.

Dynamic Stability

11. Dynamic stability was qualitatively evaluated during forward flight at 50 KIAS and OGE hover in the antenna secured configuration at the conditions listed in table 2. Aircraft short-term response was excited using forward and aft longitudinal and left and right lateral and directional control pulse inputs. Release from steady heading sideslip was also used to excite the lateral-directional response. No control movements were necessary to excite the longitudinal long-term response.

12. The longitudinal long-term response was easily excited in no turbulence. The long-term response was oscillatory. Minimal

pilot compensation was required to recover after 25 seconds to level flight to prevent exceeding V_{NE} (60 KIAS). Superimposed on the longitudinal long-term response was a slowly divergent right roll, reaching 10 deg right bank angle at the time of recovery. The longitudinal short-term response appeared deadbeat. The oscillatory long-term and apparent deadbeat short-term longitudinal responses of the UH-1 equipped with the terrain mapping receiver antenna are satisfactory.

13. The lateral-directional response to a release from steady heading sideslip resulted in a right roll. Release from a left sideslip resulted in a constant 2 deg right roll attitude. Release from a right sideslip resulted in a slowly divergent right roll and excitation of the longitudinal long-term response (para 12). The lateral-directional response to pulse inputs appeared deadbeat. However, in level flight at 45 KIAS with the antenna secured and 50 KIAS in the ferry configuration, divergent lateral-directional oscillations were encountered at one ball width (approximately 20 deg) right steady heading sideslip. The ratio of roll to sideslip was approximately 1:1 with a period of 3 seconds and a time to double amplitude of approximately 6 seconds. The oscillations were easily eliminated by reducing sideslip to less than one ball width. These oscillations were not encountered in climbs or autorotations. The lateral-directional response of the UH-1H helicopter equipped with the terrain mapping receiver antenna is satisfactory. The airworthiness release for the modified UH-1H helicopter should include the following caution:

CAUTION

Pilots should maintain the UH-1H helicopter with the receiver antenna installed or removed, in ball-centered trim. Divergent lateral-directional oscillations may be encountered with left yaw (right sideslip). These lateral-directional oscillations can be eliminated by returning the aircraft to trimmed flight.

Low Speed Flight Characteristics

14. The low speed flight characteristics in the secured and operational antenna configurations were evaluated at the conditions presented in table 2. Aircraft configurations included left cargo door open, antenna area panel removed and left cargo door closed, antenna area panel secured. Tests were conducted at a 10 foot skid height in winds 5 knots or less with true airspeed

determined by visual reference to a ground pace vehicle. Data are presented in figures 3 through 5, appendix C. There were no significant differences noted in control margins or handling qualities in the doors open and doors closed configurations. Minimum directional control margin (11%) occurred at the 45 deg relative azimuth at approximately 22 knots true airspeed (KTAS). Flight between 10 and 20 KTAS at the 45 deg relative azimuth required ±1/4 to 1/2 inch pedal inputs every 1 to 2 seconds to maintain heading within 5 deg (HQRS 5). Hovering OGE in actual winds of 15 knots at a relative azimuth of 45 degrees required frequent (every second) ±1/2 inch pedal inputs to maintain heading within 10 deg (HQRS 6). Once while attempting to stabilize on the 45 deg azimuth with a 15 knot wind, full left pedal was inadequate to arrest the right yaw. The aircraft was recovered with a slight reduction of collective and forward cyclic while maintaining full left pedal until recovery was effected. The YUH-1H Final Report (ref 8) revealed similar results with a standard UH-1H, in that hovering in actual winds was more critical than low speed flight. Airframe vibrations during low speed tests increased from VRS 3 to VRS 4 at airspeeds between 10 and 20 KTAS in all azimuths tested. Additionally, lateral vibrations in an OGE hover increased from VRS 3 to VRS 5 when hovering in 15 knot winds at the 315 deg relative azimuth. The critical azimuth was determined to be the 45 deg relative wind azimuth due to increased pilot workload and minimum control margins. Low speed flight characteristics were reevaluated at the critical azimuth with the antenna slewed to alternate positions within the operational envelope of the antenna. When accelerating the aircraft above 10 KTAS with the antenna in the full forward and aft down positions, there was a mild pitch up of the aircraft. This pitch up was controlled with approximately 1/2 inch forward longitudinal cyclic displacement. The minimum directional control margin and high pilot workload required to maintain heading during low speed flight is a shortcoming. The aircraft with the antenna installed should be restricted to operation in winds less than 15 knots and right crosswinds should be avoided.

Effects of Antenna Operation

15. The effects on the aircraft handling qualities of the antenna operating in the automatic scan mode were evaluated at a 100 foot OGE hover in 15 knot winds at the conditions presented in table 2. With the antenna stationary in the centered position, an OGE hover into the wind could be maintained within ±5 feet horizontal position and heading ±5 deg using small (1/4 inch) cyclic and directional control inputs every 1 to 2 seconds (HQRS 4). With the antenna in the automatic scan mode and a scan rate of approximately 20 deg per second, there was a noticeable increase in

pilot workload to maintain a hover. The increase in workload appeared to vary with antenna position. When the antenna was scanning aft of the centered position, frequent (every second) ±1/2 inch directional, lateral, and longitudinal control inputs were required to maintain heading ±5 deg and horizontal position ±5 feet (HQRS 6). The frequency and size of control inputs decreased slightly (HQRS 5) when the antenna was scanning forward of the centered position. Antenna operation in the automatic scan mode increased pilot workload.

AIRCRAFT SYSTEM FAILURES

Simulated Engine Failures

16. Simulated sudden engine failures were evaluated in the antenna secured and ferry configurations at the conditions presented in table 2. Sudden engine failures were simulated by a rapid reduction of the throttle to the flight idle position with controls fixed for one second or until recovery was necessary. The predominant characteristic of all simulated engine failures was a large yaw attitude change. A collective reduction delay time of up to 1.0 sec was possible during 60 KIAS level flight, however, no collective reaction delay time was possible during hovering or climbing flight. Rotor speed decayed to 270 rpm in a simulated engine failure at a hover and required 10 seconds after lowering collective to return to 324 rpm. Accelerating from 0 to 40 KIAS during autorotation resulted in an altitude loss of 700 ft and from 0 to 60 KIAS resulted in an altitude loss of 1000 ft. Nose down pitch attitudes of 10 to 15 deg were used to gain airspeed. Nose down pitch attitudes of 5 deg did not achieve an indicated airspeed increase after 1000 ft of altitude loss. Stabilizing rotor speed at 324 rpm in steady state autorotation was easy and required 1/2 inch of up collective. Maintaining minimum rate of descent airspeed, 60 KIAS (V_{NE}), was difficult (HQRS 4) due to weak static longitudinal stability (para 9). The short collective reaction delay time available following a simulated sudden engine failure at a hover is a shortcoming. OGE hover below 1000 feet AGL should be avoided due to the altitude required to obtain minimum autorotational rate of descent airspeed following a sudden engine failure.

Simulated Electrical Failure of Mission Equipment

17. Electrical failure of the mission equipment was simulated by the system operator turning off electrical power to the servo motors which position the antenna. Simulated electrical failure of the mission equipment was accomplished in a hover in 20 kts of wind. The electrical failure was simulated when the

antenna was at the centered position with the aircraft positioned into the wind. No simulated electrical failures were attempted while the antenna was in a scan pattern. The resultant motion of the antenna after power was removed was a slow rearward movement reaching the aft azimuth mechanical stop in 4 seconds. The antenna assumed a down-look angle of 12 deg. No oscillations of the antenna were observed. The antenna remained on the aft azimuth stop during 30 deg pedal turns left and right and during vertical climbs and descents of up to 100 fpm. During the vertical climbs, the down-look angle increased to 18 deg. During vertical descents, the down-look angle decreased slightly (approximately 5 deg). The aircraft handling qualities during a simulated electrical failure were the same as those noted in low speed flight (para 14). Following a simulated electrical failure the receiver antenna moved to the aft and depressed position which caused a mild pitch up in low speed flight (para 14). Aircraft handling qualities following a simulated electrical failure of mission equipment are satisfactory.

STRUCTURAL DYNAMIC RESPONSE

18. Tailboom structural dynamic response was investigated with the receiver antenna installed and removed at the conditions presented in table 2. The aircraft was instrumented with two velometers (one vertical and one lateral) mounted on a bracket attached to the inside of the tailboom access panel at boom station 175. One additional velometer was mounted vertically on the copilot instrument panel. A Chadwick-Helmuth Model 192 spectrum analyzer was used by an AVSCOM engineer onboard to record dynamic response at the tailboom location and the copilot's station. Vibration data were recorded for at least one minute during stabilized hovering, climbing, level, and descending flight. Typical UH-1H helicopter in-flight vibrations in the tailboom section were observed in hovering, level and descending flight. However, increased tailboom structural vibrations were noted in climbing flight in both the antenna secured and ferry configurations. The increased structural vibrations were observed at the frequency corresponding to the second fuselage bending mode. The second fuselage bending mode peaked at 1.6 inches per second (ips) in a 1400 fpm rate of climb at 50 KIAS with the antenna secured, but reached only 1.4 ips in a 1900 fpm rate of climb at 50 KIAS. With the antenna removed, the second fuselage bending mode showed a diminished response (0.45 ips) during the 1400 fpm rate of climb at 50 KIAS. However, the structural response increased to 1.2 ips during a 500 fpm rate of climb at 90 KIAS in the ferry configuration. The observed response at the second fuselage bending mode decreased in vertical climbs.

Although increased tailboom structural vibrations occurred in some conditions of climbing flight, the tailboom structural dynamic response in the antenna secured and ferry configurations is acceptable.

COCKPIT EVALUATION

19. The crew and cargo compartments were qualitatively evaluated throughout the test program. Electrical mission equipment was installed in the cabin area (photo 2). The only onboard fire extinguisher was located on the floor to the right of the pilot's seat. The mission equipment operator did not have immediate access to this fire extinguisher. Due to the great extent of electrical mission equipment located in the cabin area, a greater electrical fire hazard existed than in a standard UH-1H helicopter. A portable fire extinguisher should be installed in the cabin area and be accessible to the mission equipment operator in flight.

CONCLUSIONS

GENERAL

20. The modified UH-1H helicopter equipped with the receiver antenna demonstrated adequate handling qualities for the terrain mapping mission. However, the proposed mission profile requires extensive operation of the helicopter in an OGE hover. Although the handling qualities were changed from the standard UH-1H helicopter but were acceptable, the degraded autorotational characteristics may preclude a safe autorotational landing in the event of a sudden engine failure at an OGE hover below 1000 feet AGL.

SHORTCOMINGS

21. The following shortcomings were identified and are listed in order of importance:

a. The minimum directional control margin and high pilot workload required to maintain heading during low speed flight (para 14).

b. The neutral static longitudinal stability near V_{NE} (60 KIAS) (para 9).

c. The asymmetric static lateral-directional stability characteristics (para 10).

The following shortcoming was identified and is a typical characteristic of a standard UH-1H helicopter:

d. The short collective reaction delay time available following a simulated sudden engine failure at a hover (para 16).

RECOMMENDATIONS

22. The following note should be included in the airworthiness release for the modified UH-1H helicopter (para 7).

NOTE

Higher rates of descent than predicted in the operator's manual (approximately 150 fpm greater at 60 KIAS) can be expected during autorotation in the UH-1H equipped with the terrain mapping receiver antenna.

23. The following CAUTION should be included in the airworthiness release for the modified UH-1H helicopter (para 13).

CAUTION

Pilots should maintain the UH-1H helicopter with the receiver antenna installed or removed, in ball-centered trim. Divergent lateral-directional oscillations may be encountered with left yaw (right sideslip). These lateral-directional oscillations can be eliminated by returning the aircraft to trimmed flight.

24. The aircraft with the antenna installed should be restricted to operation in winds less than 15 knots and right crosswinds should be avoided (para 14).

25. OGE hover below 1000 feet AGL should be avoided due to the altitude required to obtain minimum autorotational rate of descent airspeed following a sudden engine failure (para 16).

26. A portable fire extinguisher should be installed in the cabin area and be accessible to the mission equipment operator in-flight (para 19).

APPENDIX A. REFERENCES

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9. Technical Manual, TM 55-1520-210-23, *Organizational Maintenance Manual, UH-1H/V Helicopter,* 20 February 1979 with change 14, 10 October 1985.

APPENDIX B. TEST TECHNIQUES AND DATA ANALYSIS METHODS

GENERAL

1. Established test techniques and data analysis methods were used in both the performance and handling qualities tests. The Handling Qualities Rating Scale presented in figure 1 was used to augment pilot comments relative to handling qualities. A Vibration Rating Scale (fig. 2) was used to augment pilot comments relative to vibrations. All tests were conducted in coordinated flight (ball-centered) except lateral-directional stability tests.

Autorotational Descent

2. Autorotational descents were flown at a constant rotor speed of 324 rpm and with ball-centered to determine autorotational descent performance. During the descents, the throttle was maintained at the flight idle position. The rates of descent were determined from the rate of change of the ship's pressure altitude with time and was corrected to tapeline rate of descent.

Control Rigging

3. Proper flight control rigging was verified prior to flight using the procedures outlined in TM 55-1520-210-23 (ref 9, app A).

Weight and Balance

4. The aircraft weight, longitudinal center of gravity (cg) location, and lateral cg location were determined prior to testing. The aircraft was weighed with the terrain mapping antenna installed (antenna secured) and removed (ferry configuration).

Static Longitudinal Stability

5. Static longitudinal stability was evaluated in level, climbing, and autorotational flight. The aircraft was trimmed at the desired trim airspeed. With collective fixed, the aircraft was stabilized at approximately 5 knot increments $\pm$10 knots from trim airspeed, allowing altitude, rate of climb, or rate of descent to vary as necessary. Control positions were then plotted as a function of indicated airspeed.

Static Lateral-Directional Stability

6. This test was conducted using the steady-heading sideslip method and was accomplished by establishing a trimmed flight condition and then stabilizing at incremental sideslip angles, in 1/2 ball width increments, up to 1 ball width or until full control deflection was reached, whichever occurred first. Collective

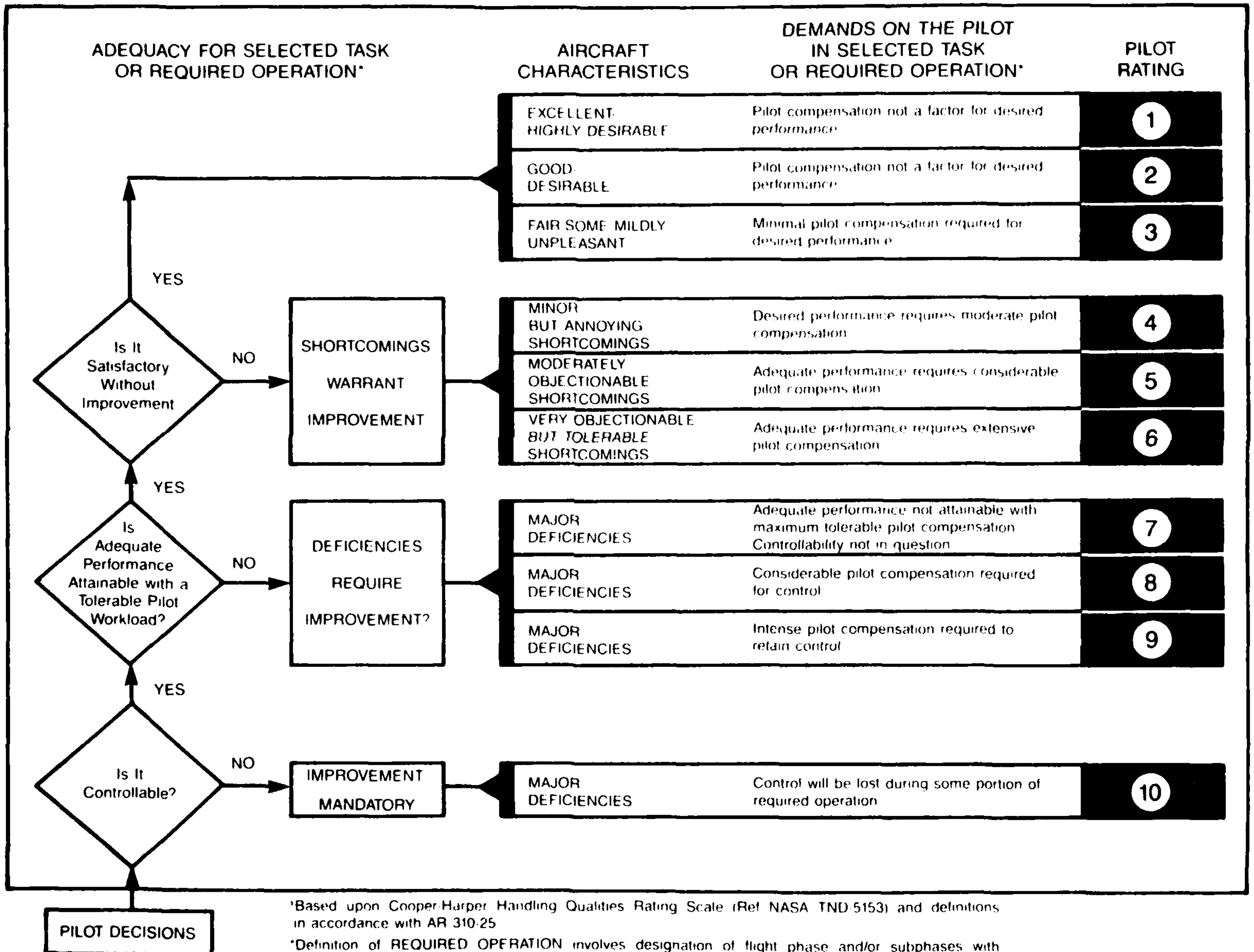
control position was fixed at the trim value and altitude was allowed to vary while maintaining the trim airspeed and desired heading. The static directional stability and dihedral effect of the aircraft were evaluated by plotting the variation of control positions with ball widths of sideslip angle.

Dynamic Stability

7. Dynamic longitudinal and lateral-directional stability were qualitatively evaluated to determine both the short and long-period characteristics. The short-period response was evaluated by use of longitudinal, lateral, and directional pulse inputs and by releases from steady-heading sideslips. The long-period dynamic response was evaluated by maintaining the controls fixed and observing the aircraft response.

Simulated Engine Failures

8. Autorotational entries were evaluated by stabilizing the aircraft at the desired condition, then simulating an engine failure by rapidly retarding the throttle to flight-idle. The controls were held fixed for 2 seconds or until a predetermined limit of 30 degrees pitch, 30 degrees yaw, 60 degrees roll, or minimum rotor speed of 250 rpm was reached, whichever occurred first.



*Based upon Cooper-Harper Handling Qualities Rating Scale (Ref NASA TND 5153) and definitions in accordance with AR 310-25

*Definition of REQUIRED OPERATION involves designation of flight phase and/or subphases with accompanying conditions

Figure 1. Handling Qualities Rating Scale

DEGREE OF VIBRATION	DESCRIPTION[1]	PILOT RATING
No vibration		0
Slight	Not apparent to experienced aircrew fully occupied by their tasks, but noticeable if their attention is directed to it or if not otherwise occupied.	1 2 3
Moderate	Experienced aircrew are aware of the vibration but it does not affect their work, at least over a short period.	4 5 6
Severe	Vibration is immediately apparent to experienced aircrew even when fully occupied. Performance of primary task is affected or tasks can only be done with difficulty.	7 8 9
Intolerable	Sole preoccupation of aircrew is to reduce vibration level.	10

[1]Based on the Subjective Vibration Assessment Scale developed by the Aeroplane and Armament Experimental Establishment, Boscombe Down, England.

Figure 2. Vibration Rating Scale

APPENDIX C. TEST DATA

Figure	Figure Number
Static Longitudinal Stability	1
Static Lateral-Directional Stability	2
Low Speed Flight	3 through 5

FIGURE 1

COLLECTIVE FIXED STATIC LONGITUDINAL STABILITY

TERRAIN MAPPING UH-1H USA S/N 66-0894

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)
8360	136.2 (MID)	0.1R	5000	5	324

NOTES:
1. TRIM FLIGHT CONDITION: LEVEL
2. SHADED SYMBOLS DENOTE TRIM
3. SECURED ANTENNA CONFIGURATION

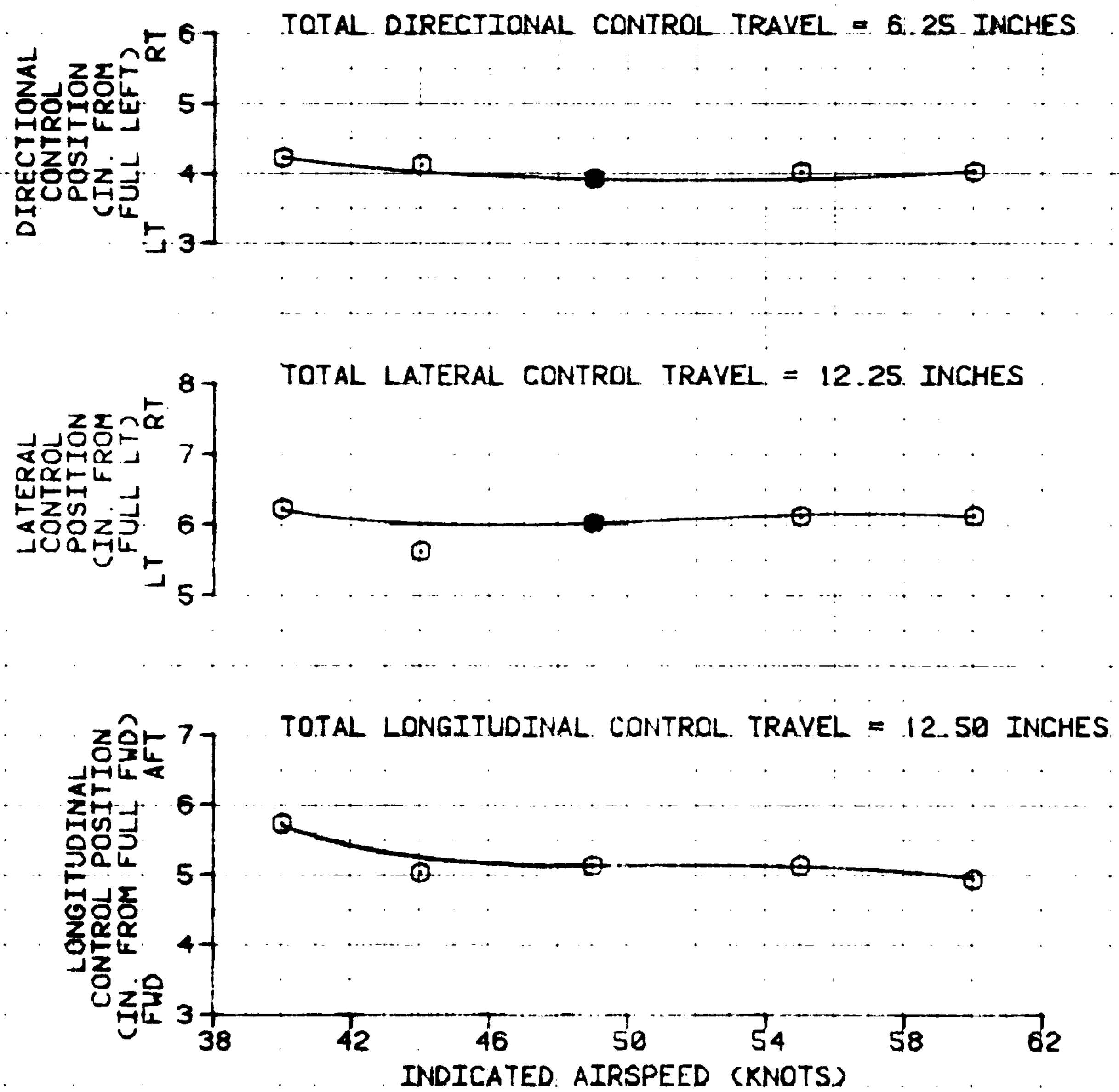


FIGURE 2
STATIC LATERAL-DIRECTIONAL STABILITY
TERRAIN MAPPING UH-1H USA S/N 66-0894

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	AVG INDICATED AIRSPEED (KTS)
8200	135.9 (MID)	0.1R	5100	6	324	50

NOTES: 1. TRIM FLIGHT CONDITION: LEVEL
2. SHADED SYMBOLS DENOTE TRIM
3. SECURED ANTENNA CONFIGURATION

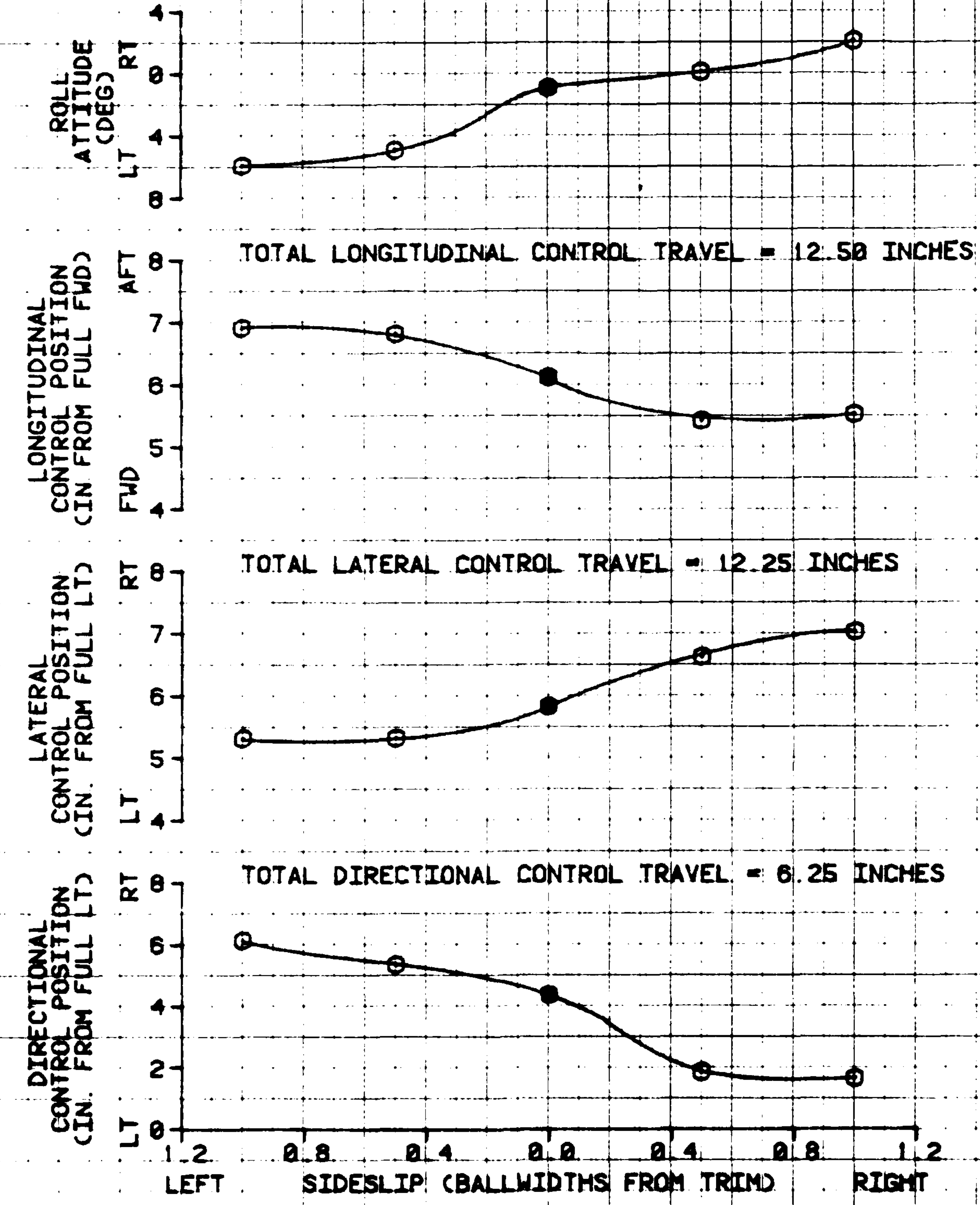


FIGURE 3

LOW SPEED FORWARD AND REARWARD FLIGHT

TERRAIN MAPPING UH-1H USA S/N 66-0894

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	SKID HEIGHT (FT)
8190	136.0 (MID)	0.1R	-1900	2.0	324	10

NOTES: 1. WIND CONDITIONS 5 KNOTS OR LESS
2. SECURED ANTENNA CONFIGURATION
3. LEFT CARGO DOOR CLOSED, ANTENNA BAY PANEL SECURED

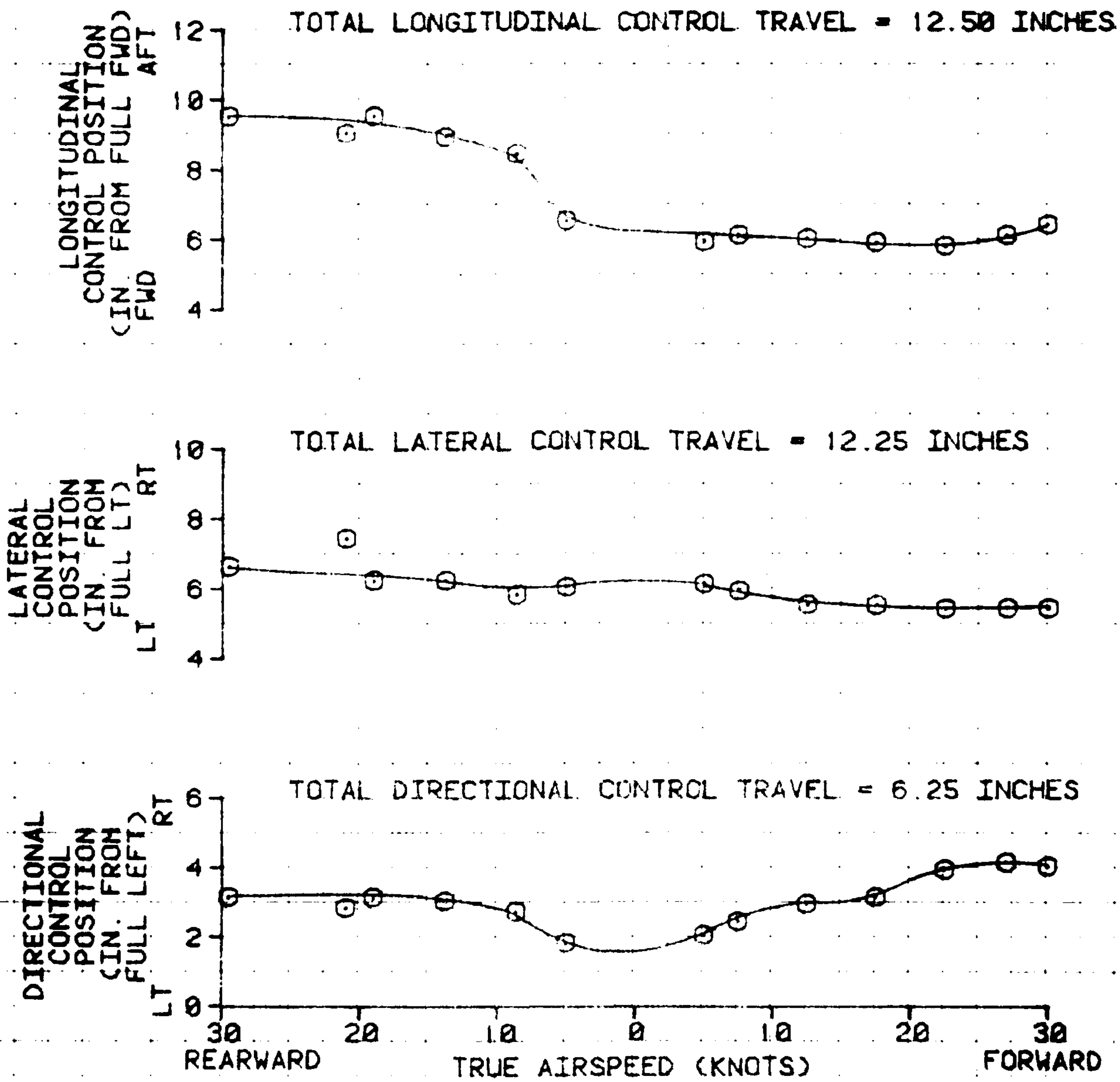


FIGURE 4

LOW SPEED LEFT AND RIGHT SIDEWARD FLIGHT

TERRAIN MAPPING UH-1H USA S/N 66-0894

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	SKID HEIGHT (FT)
8190	136.0 (MID)	0.1R	-1900	2	324	10

NOTES:
1. WINDS 5 KNOTS OR LESS
2. SECURED ANTENNA CONFIGURATION
3. LEFT CARGO DOOR CLOSED, ANTENNA BAY PANEL SECURED

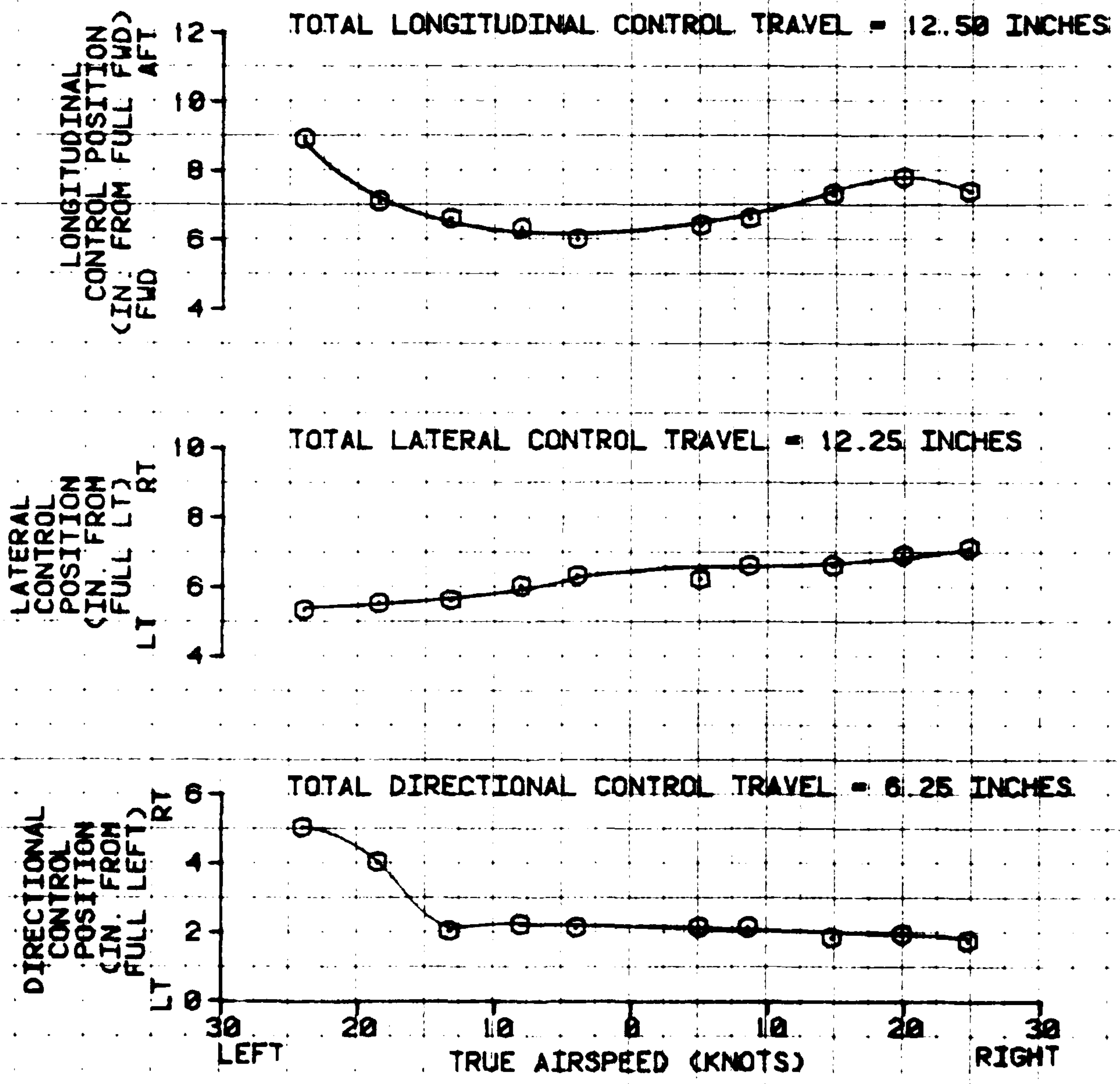


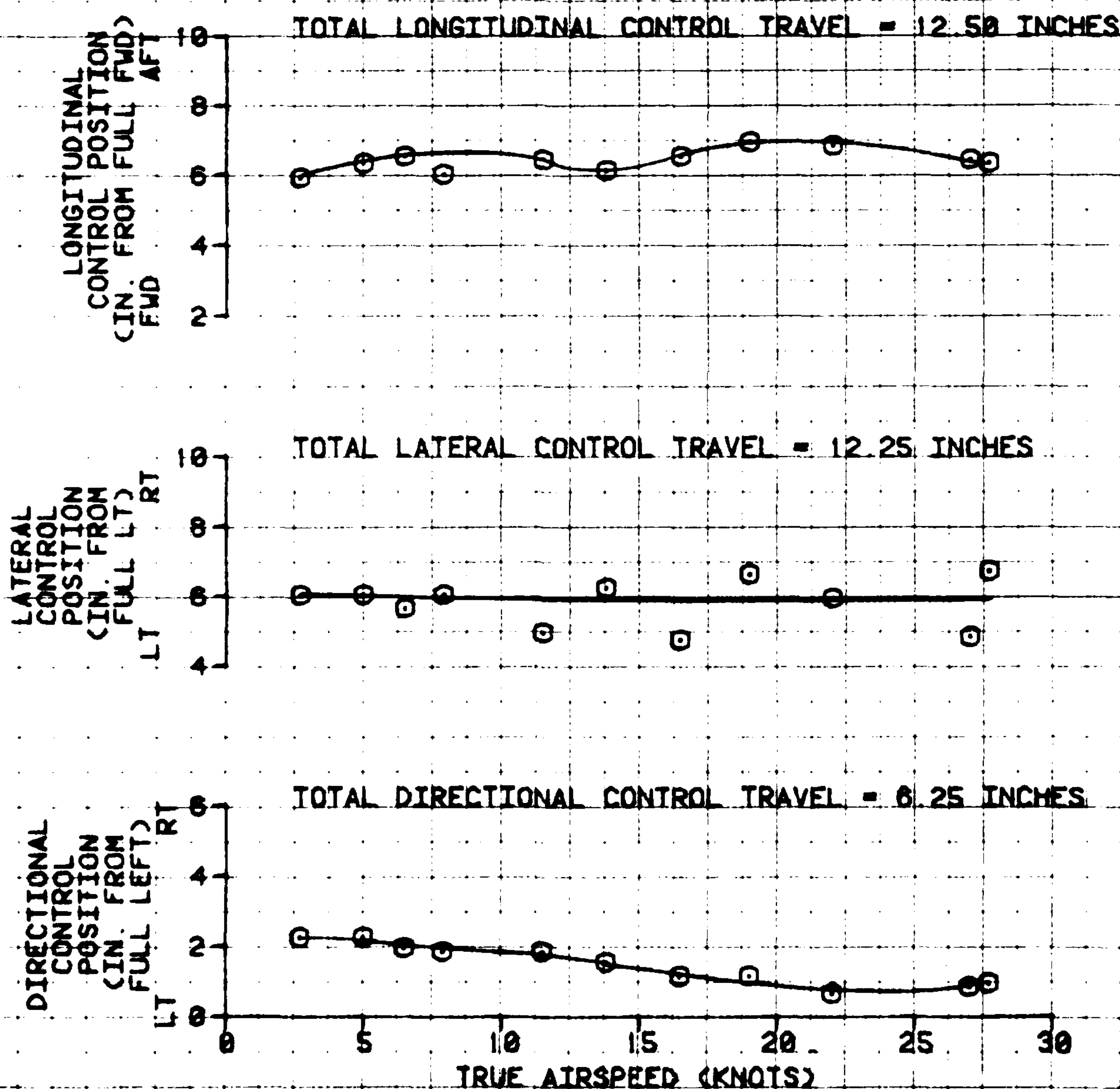
FIGURE 5

LOW SPEED 045 DEGREE AZIMUTH

TERRAIN MAPPING UH-1H USA S/N 66-0894

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	SKID HEIGHT (FT)
8190	136.0	0.1R	-1900	2	324	10

NOTES:
1. WINDS 5 KNOTS OR LESS
2. SECURED ANTENNA CONFIGURATION
3. LEFT CARGO DOOR CLOSED, ANTENNA
4. BAY PANEL SECURED



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