USAAVRADCOM-TR-82-D-35

(12)

AD A122220

VERIFICATION TESTING OF A UH-1 WIRE STRIKE PROTECTION SYSTEM (WSPS)

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November 1982

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APPLIED TECHNOLOGY LABORATORY
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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: USAAVRADCOM TR 82-D-35
2. GOVT ACCESSION NO.: A122220
3. RECIPIENT'S CATALOG NUMBER:
4. TITLE (and Subtitle): VERIFICATION TESTING OF A UH-1 WIRE STRIKE PROTECTION SYSTEM (WSPS)
5. TYPE OF REPORT & PERIOD COVERED:
6. PERFORMING ORG. REPORT NUMBER:
7. AUTHOR(s): LeRoy T. Burrows
8. CONTRACT OR GRANT NUMBER(s): House Task 82-01
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Applied Technology Laboratory, US Army Research and Technology Laboratories (AVRADCOM) Fort Eustis, Virginia 23604
10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS:
11. CONTROLLING OFFICE NAME AND ADDRESS:
12. REPORT DATE: November 1982
13. NUMBER OF PAGES: 28
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office):
15. SECURITY CLASS. (of this report): Unclassified
15a. DECLASSIFICATION/DOWNGRADING SCHEDULE:
16. DISTRIBUTION STATEMENT (of this Report): Approved for public release; distribution unlimited.
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report):
18. SUPPLEMENTARY NOTES:
19. KEY WORDS (Continue on reverse side if necessary and identify by block number):
Wire cutters
Wire strike protection
Helicopters
Flight safety
Wire deflectors
20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

In-flight wire strikes pose a serious threat to low-level helicopter operations. Under the sponsorship of Headquarters, US Army Aviation Research and Development Command (AVRADCOM), tests were conducted by ATL to determine the suitability for UH-1H helicopter application of a Wire Strike Protection System (WSPS) manufactured by Bristol Aerospace Limited (BAL). The WSPS initially tested consisted of fuselage-mounted upper and lower cutters and a windshield center-post deflector with a sawtooth cutter. Using the NASA-Langley Research Center's Impact Dynamics Research Facility, a UH-1H helicopter fitted with the WSPS was subjected to pendulum

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Block 20. Abstract - Continued.

swing tests in which the helicopter struck strung wires at approximately 40 knots airspeed. The WSPS demonstrated its capability to sever an 11,500-pound tensile strength steel, seven-strand, 3/8-inch guy wire. Also, a significant wire-cutting limitation peculiar to the UH-1H was identified. At wire impact 30 degrees from the normal to the flight path, it was demonstrated that the wire could be snagged by the windshield wiper shaft, preventing the wire from being deflected into the upper cutter. As a result, BAI and ATL analyzed the situation and both concluded that a simple windshield wiper shaft deflector could alleviate the problem. Windshield wiper shaft deflectors fabricated by BAI were installed on the test aircraft and additional swing tests were conducted. Successful deflection and wire cutting were demonstrated. Installation of the WSPS, as modified by this effort, on the Army's UH-1H helicopter fleet is recommended.

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PREFACE

The project engineer for the tests described herein was LeRoy T. Burrows, Aerospace Engineer, Safety and Survivability Technical Area, Aeronautical Systems Division, Applied Technology Laboratory (ATL). The lead aerospace technician was Mr. Paul Triplett, also of ATL.

The author extends his gratitude to the following organizations for the support specified:

- NASA-Langley Research Center (LRC) for providing facility and fabrication support, conducting the pendulum swings of the aircraft, and providing external photographic coverage.
- HQ, AVRADCOM for requesting and funding these tests.
- US Army Transportation School, Department of Aviation Systems, for lending the test vehicle.
- US Army Transportation Center and Fort Eustis Directorate of Facilities Engineering, Utilities Division, Electrical Branch, and the US Army Communications Command Detachment, Fort Eustis, for erecting the wires for these tests.
- ATL Technical Services Division for preparing the test vehicle and providing photographic coverage.
- ATL Aviation Test Support Facility for preparing the vehicle and moving the aircraft.

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INTRODUCTION

In-flight wire strikes are a serious threat during all-weather daytime and nighttime helicopter operations, including:

- Terrain flight (nap-of-the-earth, low-level, and contour)
- Enclosed area takeoff and landing
- Confined area maneuvering

The US Army's growing emphasis on these operations is a major reason for the recent increase in wire strikes experienced. Despite concentrated training in how to avoid wire strikes, and actions such as mapping wires in training areas, removing unnecessary wires, marking cables with orange spheres or other devices, and preparing SOP's to increase pilot awareness of the wire strike threat, the peacetime wire strike problem remains a serious one. During the period 1 January 1974 to 1 January 1980, wire strikes accounted for 8 percent of total Army aircraft damage, 6 percent of all Army aircraft injuries, and 16 percent of Army aviation fatalities. During this period, none of the fatalities were a result of main or tail rotor blades striking wires, indicating that fuselage and skid gear strikes are the primary problem. Since many of these mishaps have occurred during training over familiar sites, it can be assumed that the wire impact threat posed by combat operations in unfamiliar areas would result in increased wire strikes. Furthermore, in a hostile environment the enemy can be expected to string wires as an intrusion countermeasure.

Since the emphasized operations require flight close to the ground during varying degrees of visibility, the hazards presented by wires and other obstacles cannot be eliminated. However, these hazards can be effectively reduced by configuring the helicopter system to be more tolerant of them. Increasing helicopter survivability to the wire strike threat will result in fewer mishaps, and therefore increased aircraft availability, decreased maintenance, reduced casualties, and improved mission effectiveness.

A simple, cost-effective design approach to providing protection from the wire strike threat is a helicopter Wire Strike Protection System (WSPS) designed by Bristol Aerospace Limited (BAL) under contract to the Canadian National Defence Headquarters. For the OH-58 helicopter this system consists of an upper cutter, a lower cutter, and a windshield centerpost deflector. An examination of electric power and telephone lines in use revealed that a 3/8-inch-diameter, seven-strand steel messenger cable with a tensile strength in excess of 10,000 pounds was the toughest cable found in abundance. This type of cable had been the cause of many fatal helicopter accidents. Accordingly, the WSPS was designed to counter the threat of this cable or wire, which was designated the design objective wire. This wire is normally used to support heavy communications cables that contain many copper wires within.

In May 1979, the Canadian WSPS was qualified for Canadian KIOWA helicopter (OH-58A) application. BAL conducted a series of 52 wire-cutting tests by mounting a deflector and upper cutter on a wrecked KIOWA fuselage, rigidly securing this to the flatbed of a truck, and driving the truck into fixed wires. Test variables included speed (15 to 60 mph), yaw angle (0 to 45 deg), strike location (nose to top of cutter), and wires (steel-reinforced aluminum, 10M, and guy cables). Concurrently, the Canadian Aerospace Engineering Test Establishment conducted a flying qualities (FQ) and electromagnetic interference (EMI) qualification test of the OH-58A with the WSPS installed. All wire-cutting tests were successful, and no significant effects upon aircraft FQ and EMI were noted.

The wire-cutting test method employed by BAL validated upper cutter and deflector design objectives but did not test the lower cutter. Neither were questions answered regarding aircraft pitch and yaw attitude changes or deceleration loads attendant to the wire impact and cutting sequence, or their potential effects upon aircraft control and blade flapping. These questions were answered by OH-58A swing tests conducted by ATL in October 1979 and reported in Reference 1. The wire impact/deflection/cutting sequence did not have a significant effect on the OH-58A helicopter with respect to attitude change, impact loads, or blade flapping calculations.

The UH-1 WSPS configuration is similar to that of the OH-58 system. For this reason the Canadian Armed Forces procured a WSPS for their IROQUOIS fleet without subjecting it to verification testing. Flight tests were conducted to ensure that the WSPS would not affect aircraft FQ and EMI. Prior to the application of the WSPS to the US Army's UH-1 fleet, AVRADCOM desired verification swing testing similar to that conducted by ATL for the OH-58 WSPS. This report describes the UH-1 WSPS verification tests.

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[1] L. T. Burrows, *Investigation of Helicopter Wire Strike Protection Concepts*, USAAVRADCOM TM 80-D-7, Applied Technology Laboratory, US Army Research and Technology Laboratories (AVRADCOM), Fort Eustis, Virginia, June 1980, AD A086857.

TEST PURPOSE

The purpose of this test program was twofold:

1. To determine the performance of the WSPS for the case of cable impact on the windshield at an angle 30 degrees from the normal to the flight path. Specifically, to answer the following questions: (a) Would the plate glass windshield break? (b) Would breakage deter cable deflection to the cutter? (c) Would the cable hang up on the windshield wiper shaft and not deflect into the cutter?

2. To demonstrate that the UH-1H WSPS would, in fact, cut the objective cable and provide structural enhancement to the windshield center post.

TEST FACILITY

The UH-1H WSPS test was performed at the Impact Dynamics Research Facility shown in Figure 1. The basic structure of the facility is the 220-foot-high by 400-foot-long gantry. It is supported by three sets of inclined legs spread 267 feet apart at the ground level and 67 feet apart at the 218-foot level. A movable bridge spans the gantry at the 218-foot level and traverses the length of the gantry. A control room and an observation room are located in the building at the base of the gantry. Along the centerline of the gantry, at ground level, is a strip of reinforced concrete 400 feet long, 30 feet wide, and 0.67 foot thick.

The apparatus necessary to conduct a helicopter pendulum swing test is shown in Figure 2. Swing-cable pivot-point platforms located at the west end of the gantry supported the winches, sheaves, and pulley systems that controlled the length of the two swing cables. A pullback platform attached to the underside of the movable carriage supported the winch, sheave, and pulley system that controlled the length of the pullback cable. Swing cables were attached to the helicopter rotor hub and, during the pendulum swing, supported the helicopter through the rotor mast, as it would be in free flight. A pullback cable with an electrically operated hook was attached to a fixture placed on the aft end of the tail boom.

Both swing and pullback cables could be varied in length to provide desired pendulum swing arc and velocity. For a wire height of 22 feet, the pullback position shown in Figure 2 was calculated to provide the desired wire impact velocity.

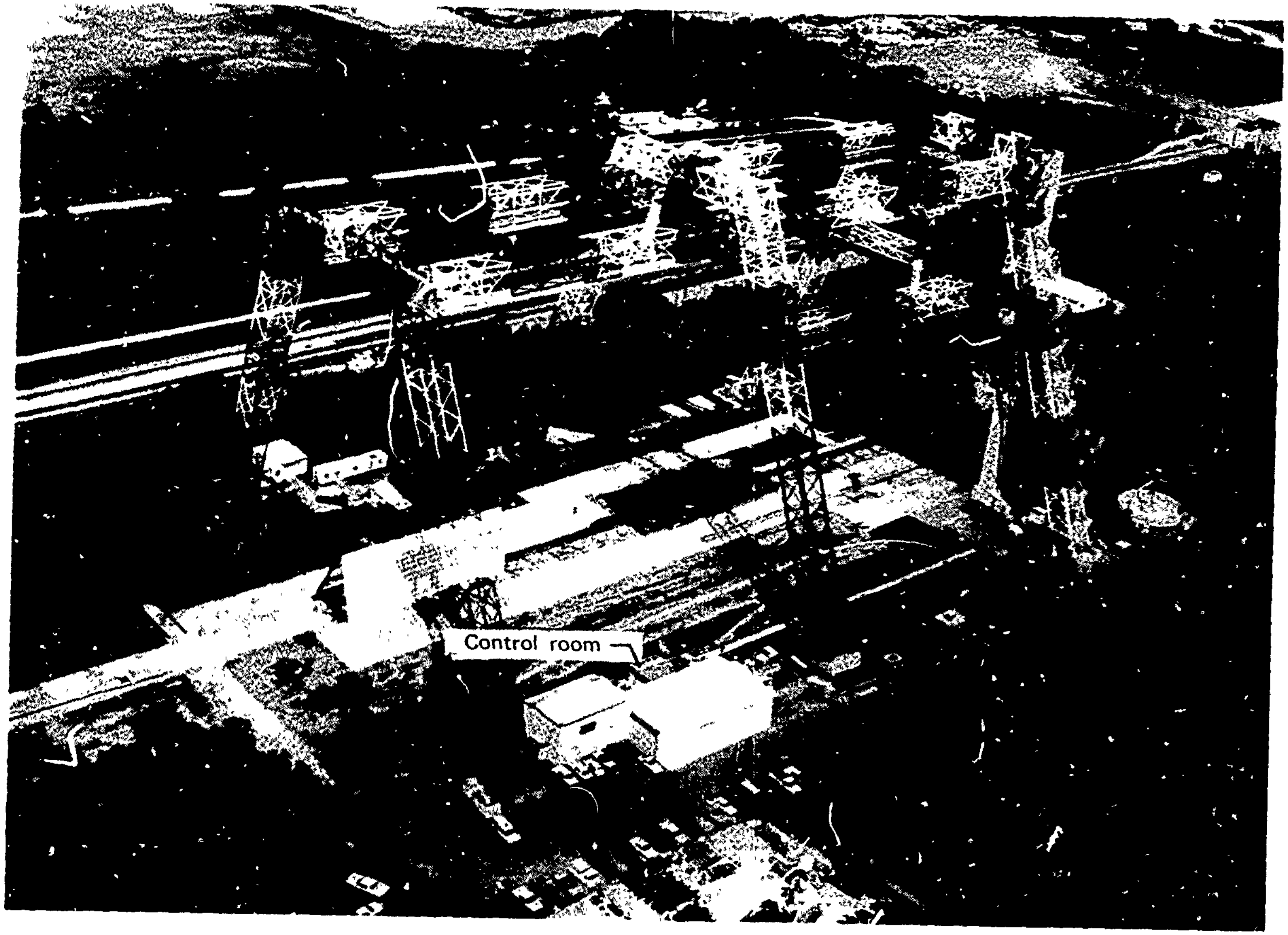

Figure 1. Impact Dynamics Research Facility.

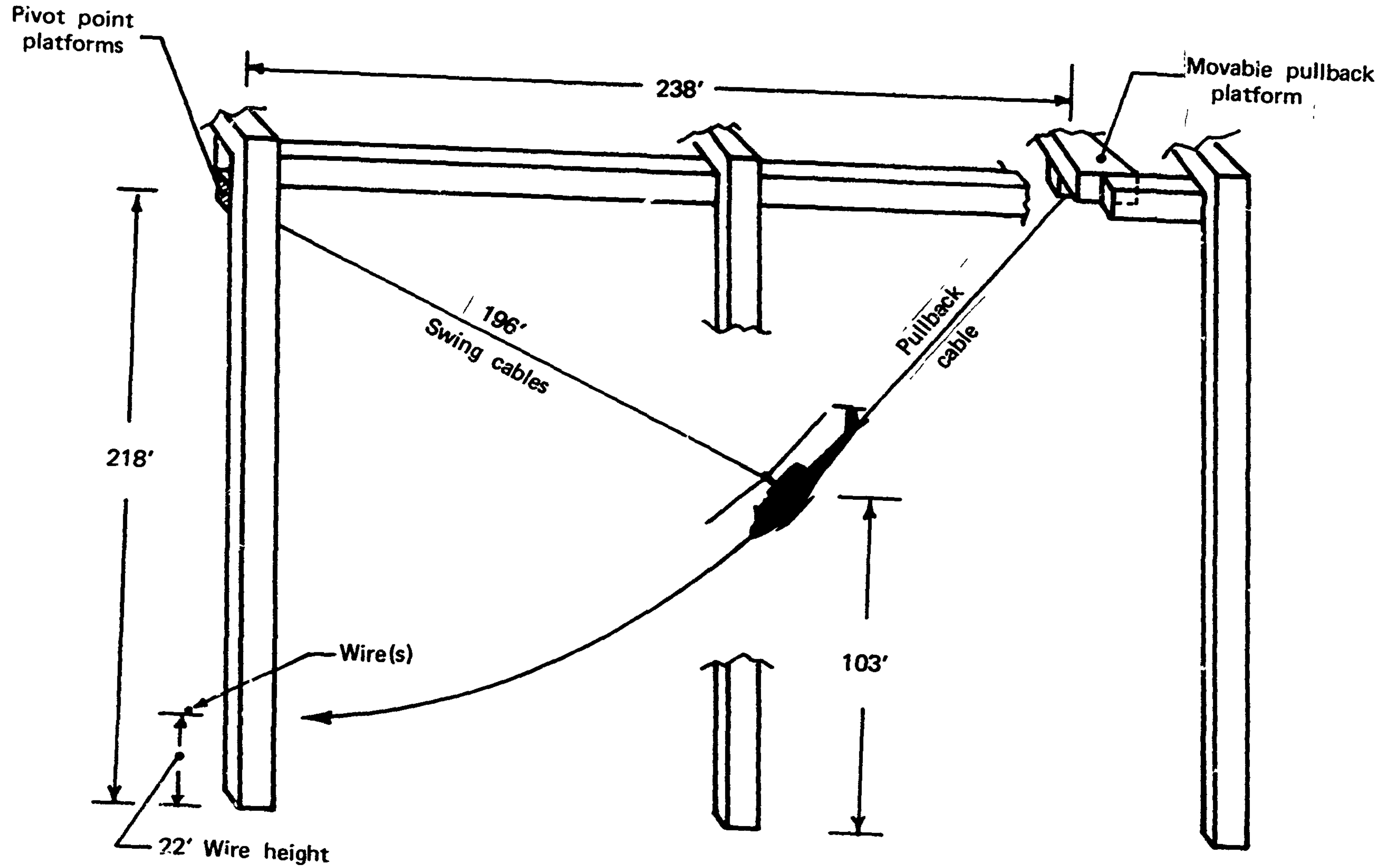

Figure 2. Pendulum swing test apparatus.

TEST SETUP

AIRCRAFT PREPARATION

The WSPS test specimen was a UH-1H helicopter that had been retired from service and was being used for maintenance training by the US Army Transportation School. It was fully equipped less avionic equipment. The aircraft was initially prepared for testing at the ATL Aviation Test Support Facility as follows:

1. Removed Plexiglas windshields and installed standard plate glass windshields.

2. Installed the UH-1H WSPS.

3. Fabricated and installed fixtures to prevent rotor head movement in any direction.

4. Fabricated and installed on-board camera mounts and the circuitry and fixtures required to actuate the cameras via a lanyard.

5. Added fixtures for swing and pullback cable attachment.

6. Calculated weight and balance and added ballast required to place the center of gravity (cg) at the rotor mast station.

A CH-47 helicopter was used to transport the test vehicle to the test site (Figure 3) where the weight and cg location were adjusted to obtain a "skid level" attitude at wire impact. This resulted in a vehicle gross weight of 5027 pounds with the cg 4 inches aft of the mast station.

WIRE STRIKE PROTECTION SYSTEM (WSPS)

The Canadian WSPS initially tested is shown installed on the test aircraft in Figures 4 and 5. This is a cutter/deflector system with an upper cutter to protect the main rotor controls; a lower cutter to protect the skid gear; and a windscreen center-post deflector with a serrated cutting edge insert to deflect wires to the upper cutter and/or cut them, and to reinforce the center-post structure. The WSPS is a passive system, having no moving parts. Upon wire impact, the helicopter momentum deflects the wire or cable into the upper or lower wedge-shaped cutter, which notches it to the extent required for tensile failure. Installation of the WSPS required approximately 35 man-hours.

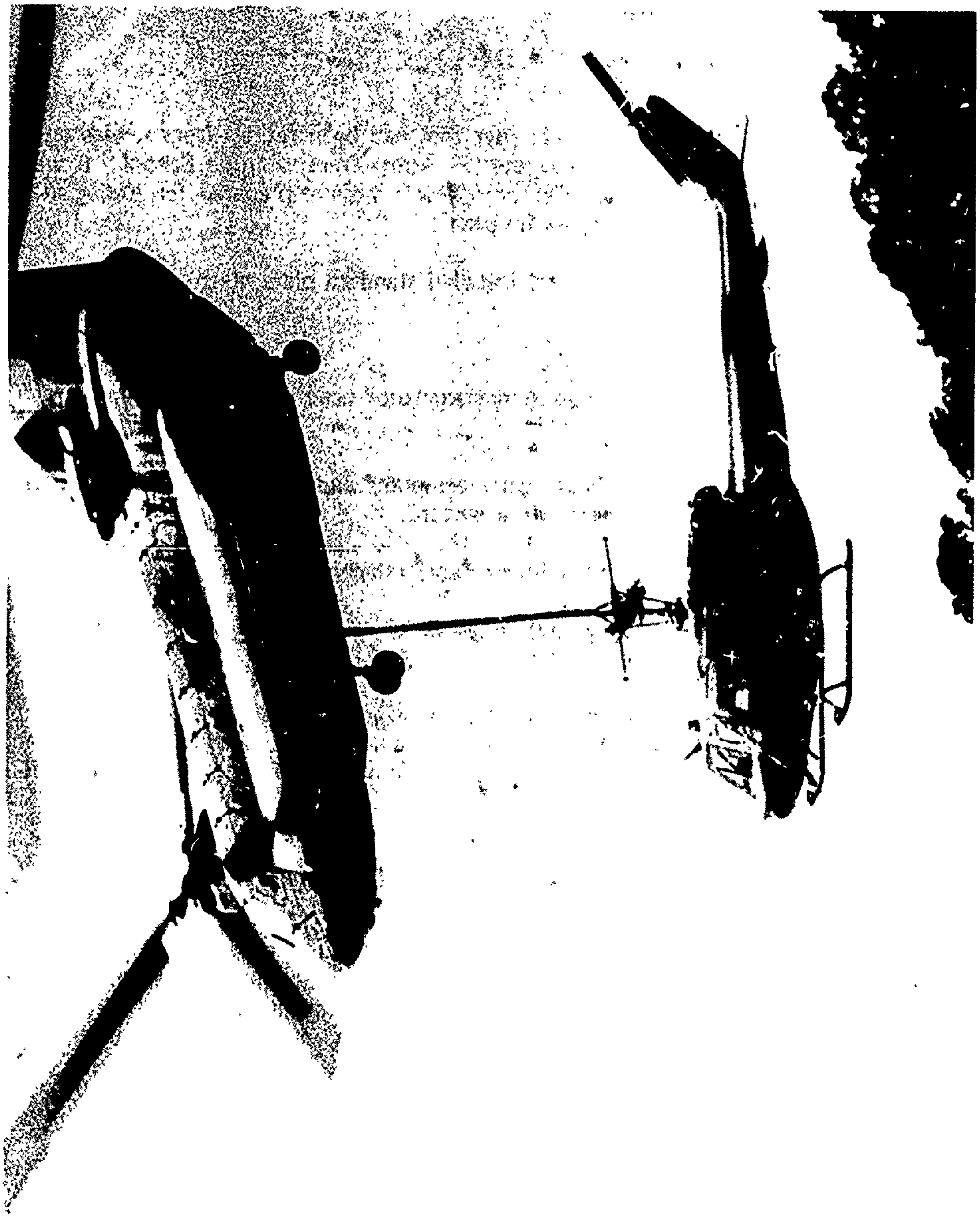

Figure 3. CH-47 transport of UH-1.

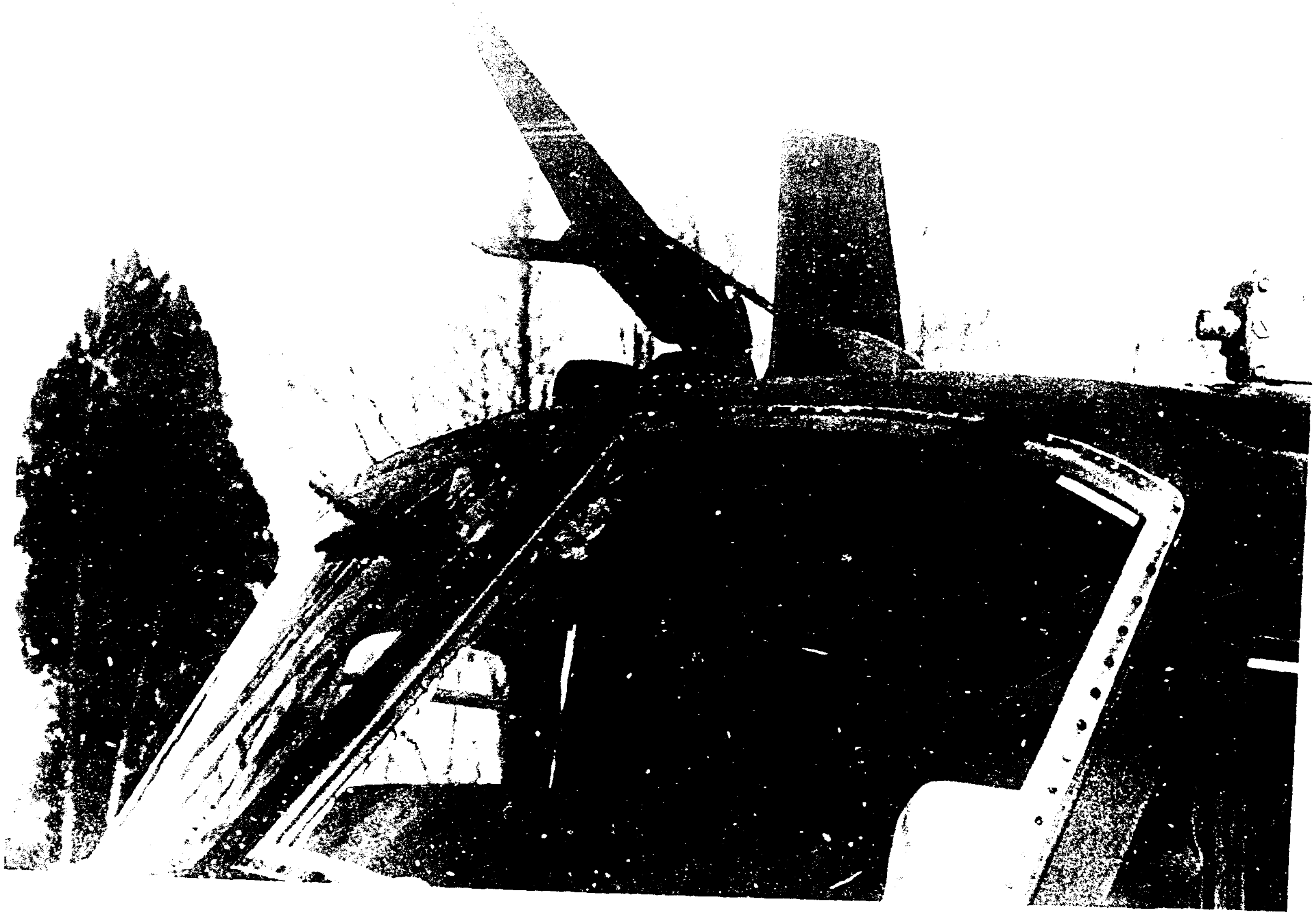

Figure 4. WSPS upper cutter and center-post deflector.

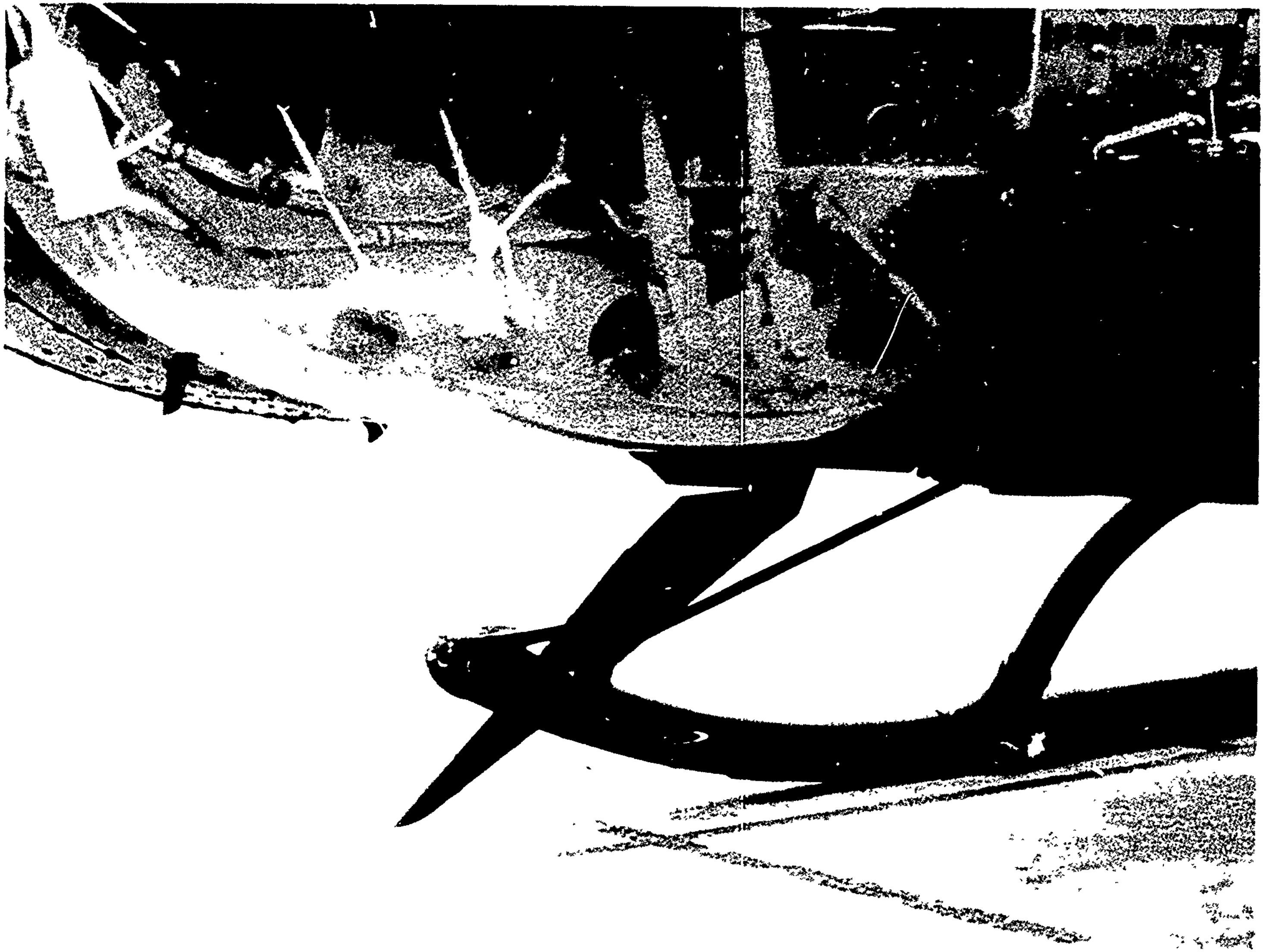

Figure 5. WSPS lower cutter.

OBJECTIVE WIRE

Four communication/power line poles were erected at the test site approximately 200 feet apart to permit stringing of the objective wires 30 degrees from the normal or normal to the predicted aircraft flight path. Use of a 200-foot wire strung at a standard height and tensioned by the line crew in accordance with normal procedures provided the basis for a realistic wire installation. The wire was strung approximately 10 feet forward of the swing-cable pivot-point platforms at 22 feet above ground level. This permitted raising and lowering the aircraft to a pre-pullback position without wire interference. For the tests, a 3/8-inch-diameter, seven-strand guy wire supporting a section of 50-pair communications cable of 0.85-inch diameter, containing 100 copper wires, was used. The guy wire used had a tensile strength of 11,500 pounds and was slightly stronger than the planned 10M wire, which could not be obtained.

PHOTOGRAPHIC AND RADAR COVERAGE

Two high-speed (400 frames/sec) 16mm motion picture cameras were installed on the test helicopter. One was mounted in the cockpit to provide a pilot's eye view during the tests; the other was mounted on top of the aircraft to permit a view of the upper cutter performance. A 10mm wide-angle lens was used with both on-board cameras because of its wide field of view and its ability to obtain visual data at close range. These cameras were powered by an on-board NiCad battery and were activated through circuitry and a lanyard switch. At the T minus 3 seconds point of the aircraft release countdown the lanyard pin was manually pulled, thus permitting camera run-up prior to release.

Exterior high-speed and still sequence motion picture photography was provided by NASA. Hand-held real time and rapid sequence cameras were operated by ATL photographers. Ground coverage included four high-speed (650 frames/sec) ground cameras and two 70mm still sequence (50 frames/sec) cameras.

Radar was set up by NASA personnel to measure helicopter velocity at wire impact. A stand-mounted continuous-wave Doppler radar system was used.

TEST DESCRIPTION

For each test, the UH-1H was lifted by the two swing cables to a height that would provide the desired location of initial wire impact. For the windshield impact test with the wire at an angle 30 degrees from the normal, wire impact location was selected to be at a height about one-third up the windshield side post. For the test with the cable normal to the flight path, the selected wire impact point was on the windshield center post approximately 4 inches above the nose.

In estimating lift height or swing cable length to obtain the desired impact location, swing cable elongation under dynamic loads must be considered. For these tests the vehicle pulled approximately 1 g additional acceleration at the base of the swing which, for the size swing cables used, equates to an elongation of approximately 5 inches. The swing cables were attached to the rotor hub by a ring attachment that would allow pitching movement of the aircraft independent of the swing cables. The aircraft was then drawn back to the release position by the pullback cable. The pullback height was calculated to provide a pendulum swing flight path that would result in the planned wire impact conditions listed in Table 1. The 40-knot impact speed was selected as representative of terrain flight operations. Although airspeed at impact could have been varied, the adverse weather and short time of facility availability, coupled with the time and cost of wire erection, precluded additional testing.

The test schedule is shown in Table 2. Tests 5 and 6 were added to verify a windshield wiper post deflector concept.

TABLE 1. AIRCRAFT CONDITIONS AT WIRE IMPACT

	Planned	Actual*
Airspeed, kn	40	40 ± 1
Pitch angle, deg	0	-5 to +3
Yaw angle, deg	0	±5
Roll angle, deg	0	0

*Varied because of wind and swing dynamics.

TABLE 2. PENDULUM SWING TEST SEQUENCE

Test No.	Test	Date	Objective Wire/ Aircraft Orientation	Objective Wire Impact Point
1	Aircraft stability	2 Dec 81	–	–
2	Aircraft stability	3 Dec 81	–	–
3	Upper cutter	7 Dec 81	30 deg from normal	Windshield one-third up side post
4	Upper cutter	10 Dec 81	Normal	Windshield center post
5	Upper cutter	9 Mar 82	30 deg from normal	Windshield one-third up side post
6	Upper cutter	10 Mar 82	30 deg from normal	Deflector for windshield wiper post

TEST RESULTS

TESTS 1 AND 2

Tests 1 and 2 were conducted without wires erected to ascertain the aircraft motion during a pendulum swing while supported only through the rotor mast. Neither of these tests resulted in erratic flight motions, indicating that no further restraint of the aircraft during the wire impact tests was required. During these stability check swing tests and subsequent tests, it was noted that due to the symmetry of the vertical stablizer, the test aircraft did not yaw during a free swing. However, there was a tendency for it to align with wind direction. For this reason, wire-cutting tests were limited, when possible, to times when the wind direction was favorable. Table 1 depicts the actual pendulum swing conditions at the point where there would be wire impact.

TEST 3

For this test the wire impact point was to be on the windshield at a point approximately one-third up the side post. The wire was strung at an angle 30 degrees from the normal to the flight path. The pre-pullback position of the helicopter is shown in Figure 6 and the pullback position in Figure 7. The aircraft impacted the cable at the desired location and velocity without damage to the glass windshield. The cable then deflected upward to the windshield wiper shaft, where it snagged. The structure behind the wiper shaft collapsed, allowing the cable to enter the upper cockpit area and preventing it from deflecting to the upper cutter. In the absence of a cable cut, the supporting line pole broke into three sections, and two anchors were pulled out. The resulting damage to the test helicopter is depicted in Figures 8, 9, and 10 which show side, front, and top views respectively. It was obvious that the windshield wiper shaft posed a serious limitation to the WSPS configuration tested. Both BAL and ATL, with Headquarters, AVRADCOM concurrence, agreed to investigate means of alleviating this limitation with minimum cost, weight, and performance penalties.

TEST 4

Notwithstanding the wiper shaft limitation, it was decided to retest to verify the performance of the windshield center post deflector and the upper cutter. Aircraft restoration began almost immediately, and the aircraft was ready for test in two days. In this test the wire was impacted on the windshield center-post deflector where it bounced along the serrated cutting edge insert and was cut before it could deflect to the upper cutter. Film analysis of this test indicated momentary snags of the wire on the center-post deflector as the wire gouged out teeth from the serrated cutting edge insert. Although the serrated cutting edge insert did not cut the cable, it retarded deflection to the upper cutter, which is the primary cutting mechanism, and in the process, imparted higher loads on the center post than would be experienced without the serrated edge. This could be critical for higher speed impacts (e.g., 90 knots).

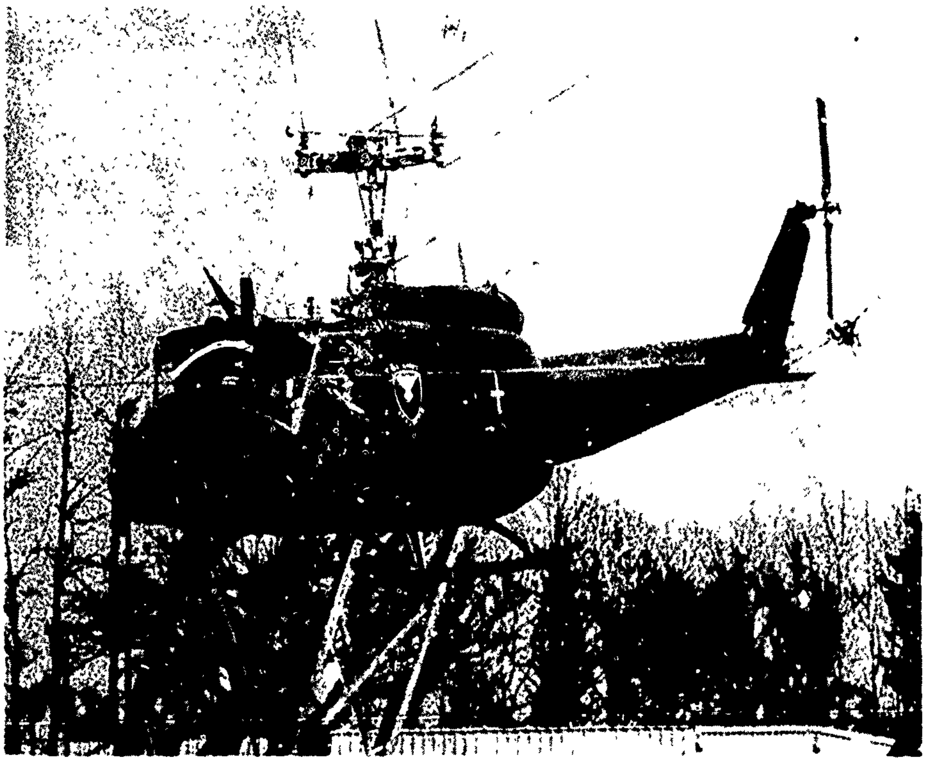

Figure 6. Test aircraft in pre-pullback position.

Figure 7. Test aircraft in pullback position.

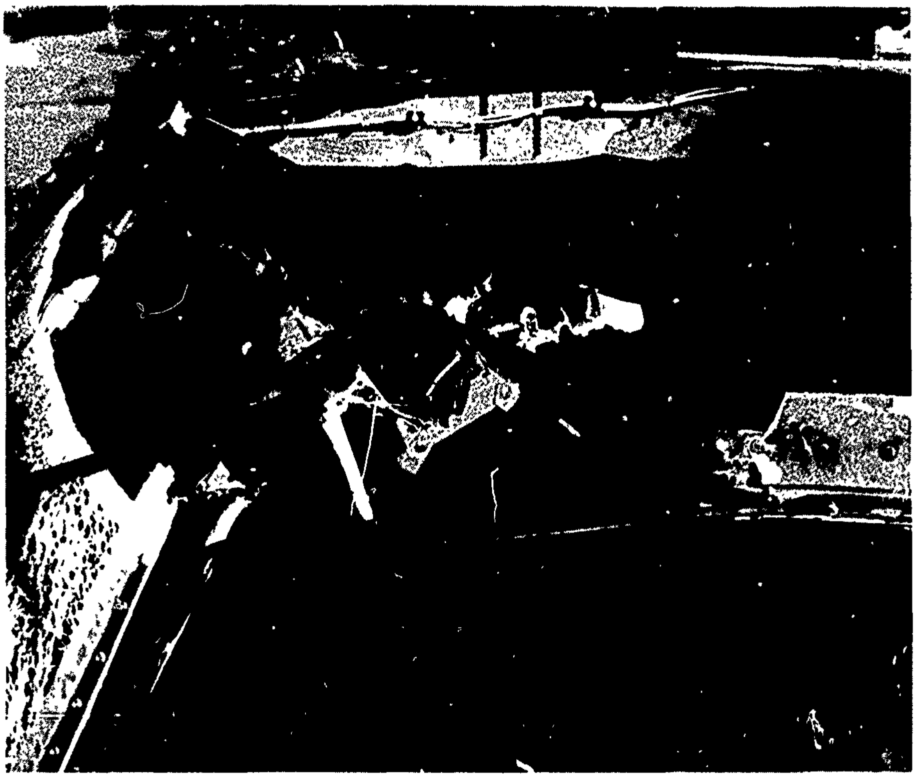

Figure 8. Test 3 aircraft damage, side view.

Figure 9. Test 3 aircraft damage, front view.

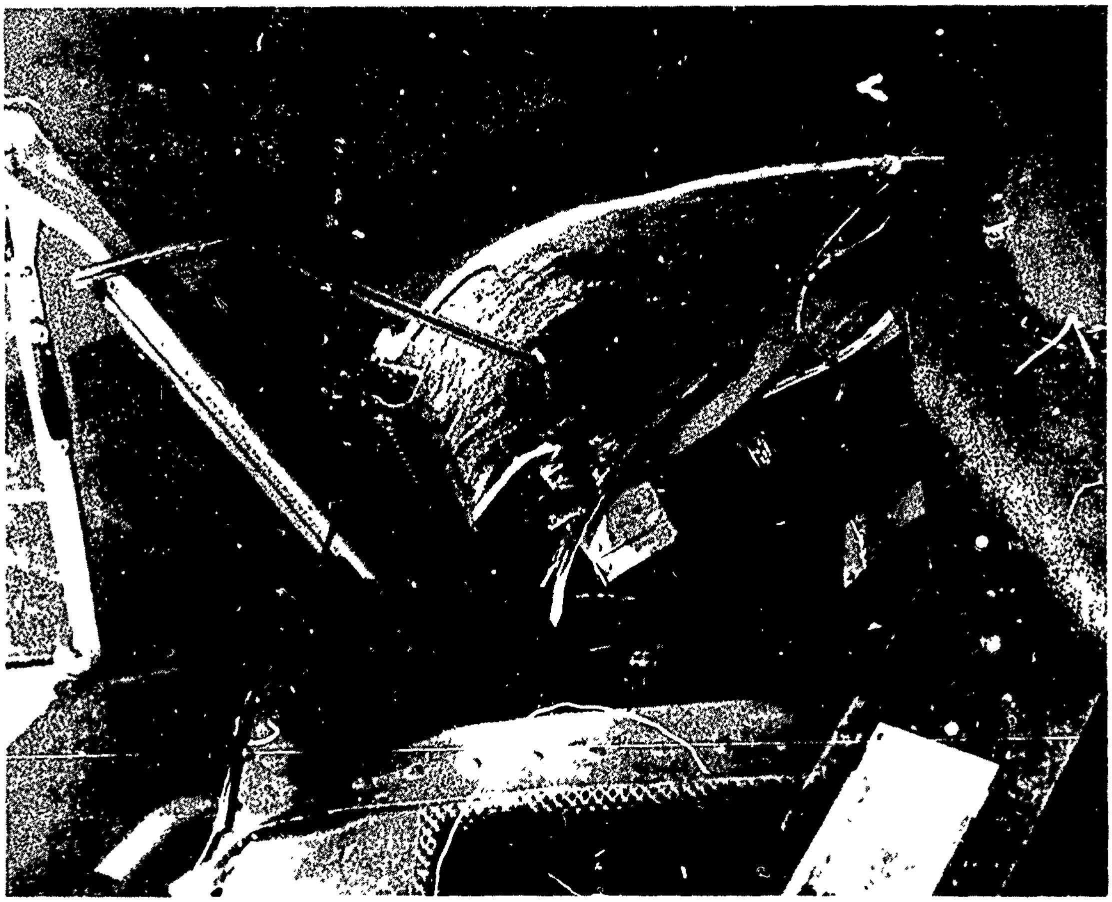

Figure 10. Test 3 aircraft damage, top view.

TEST 5

A windshield wiper post deflector designed and fabricated by BAL ..as installed on the test aircraft (Figure 11). The aircraft was swing tested at the same conditions as Test 3 and a successful cut of the objective wire resulted (Figure 12), thus eliminating the wiper post as a snag problem. Figure 13 shows the aircraft after test. Note the paint marks on the windshield which depict wire impact location below the wiper deflector and subsequent deflection over the wiper into the upper cutter.

TEST 6

This test was conducted under the same conditions as Tests 3 and 5 except that impact on the wiper deflector was desired to verify its attachment strength. The paint markings seen in Figure 14 show that the wiper deflector was impacted. No post-tested structural deformation was evident in any components of the WSPS. It was also demonstrated that the sheet metal wiper stop, the wiper itself, and the air scoops on top of the canopy are not significant snags. These sheet metal parts just bend or tear as the wire deflects past them into the upper cutter (Figure 15).

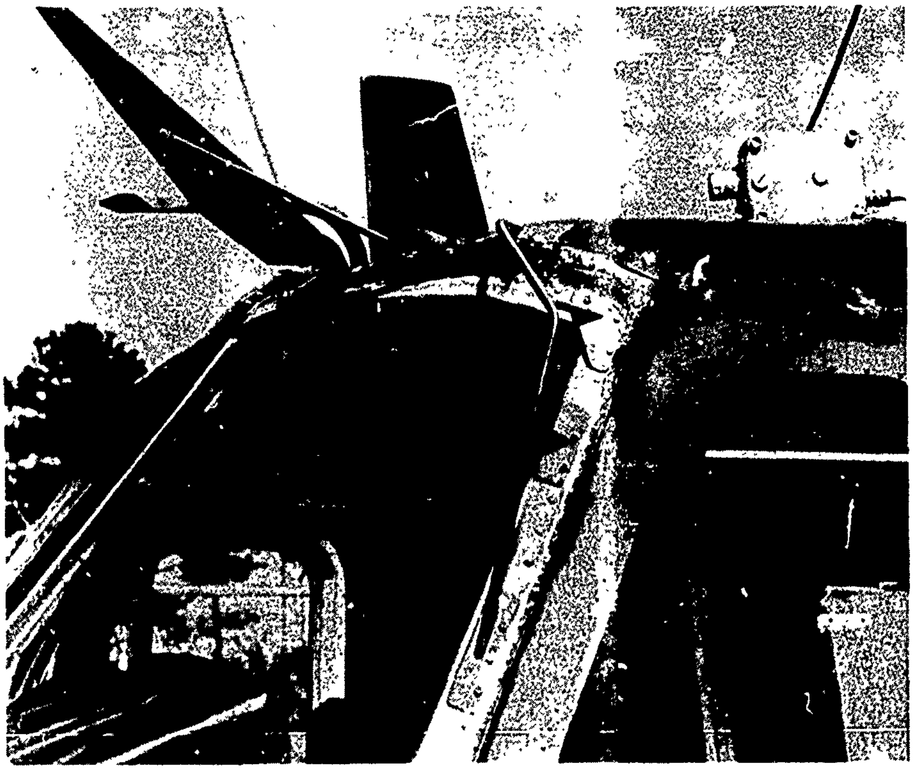

Figure 11. Windshield wiper post deflector.

Figure 12. UH-1 WSPS objective wire cut.

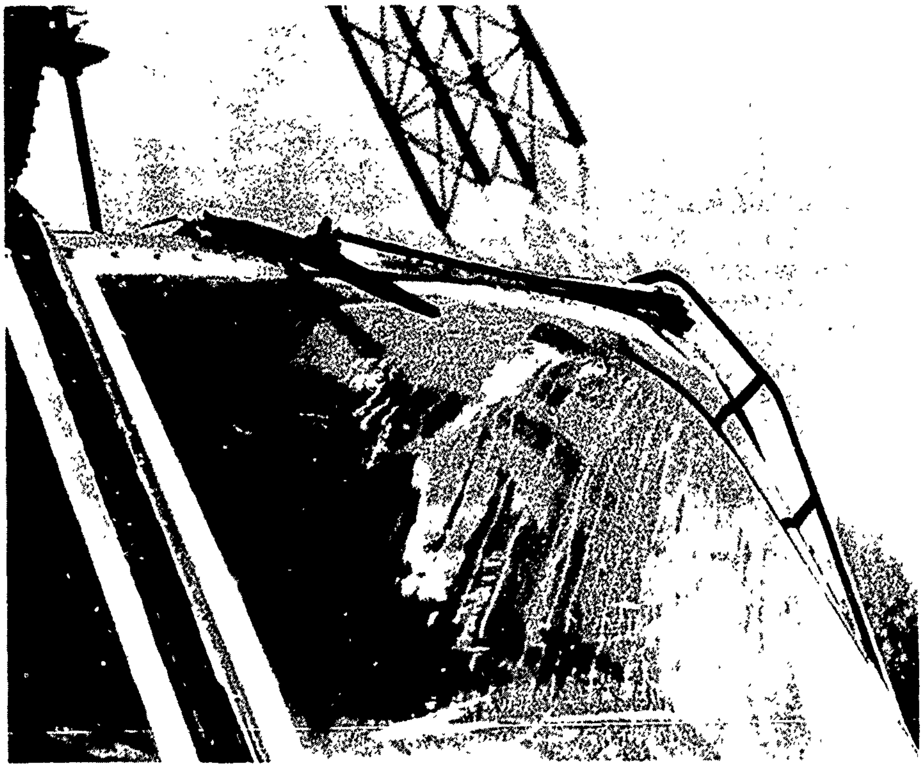

Figure 13. Aircraft condition after test 5.

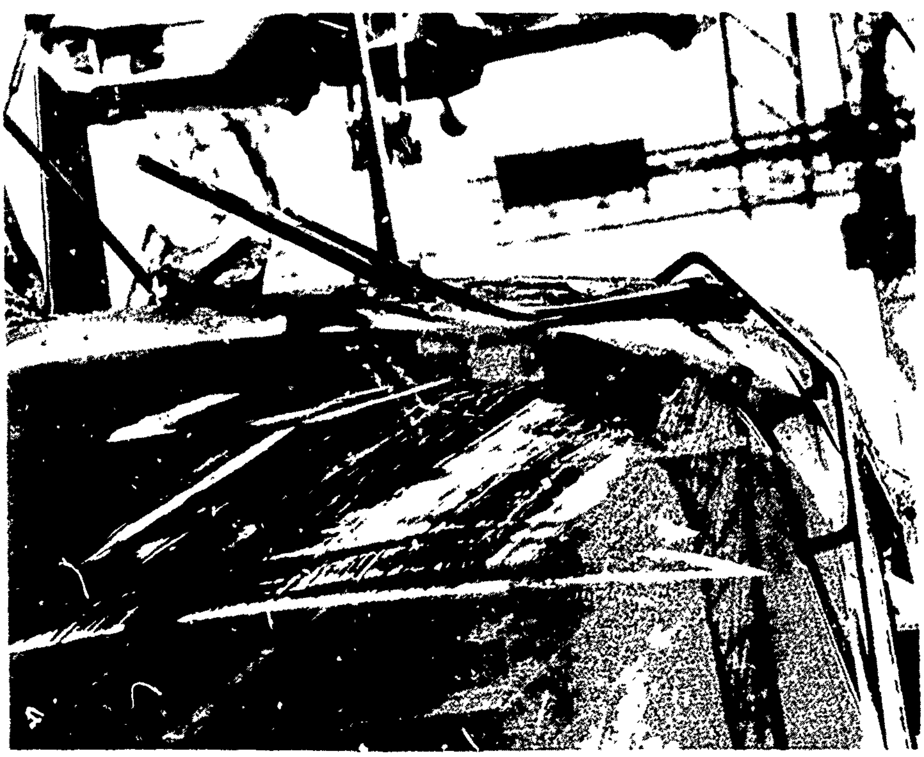

Figure 14. Aircraft condition after test 6.

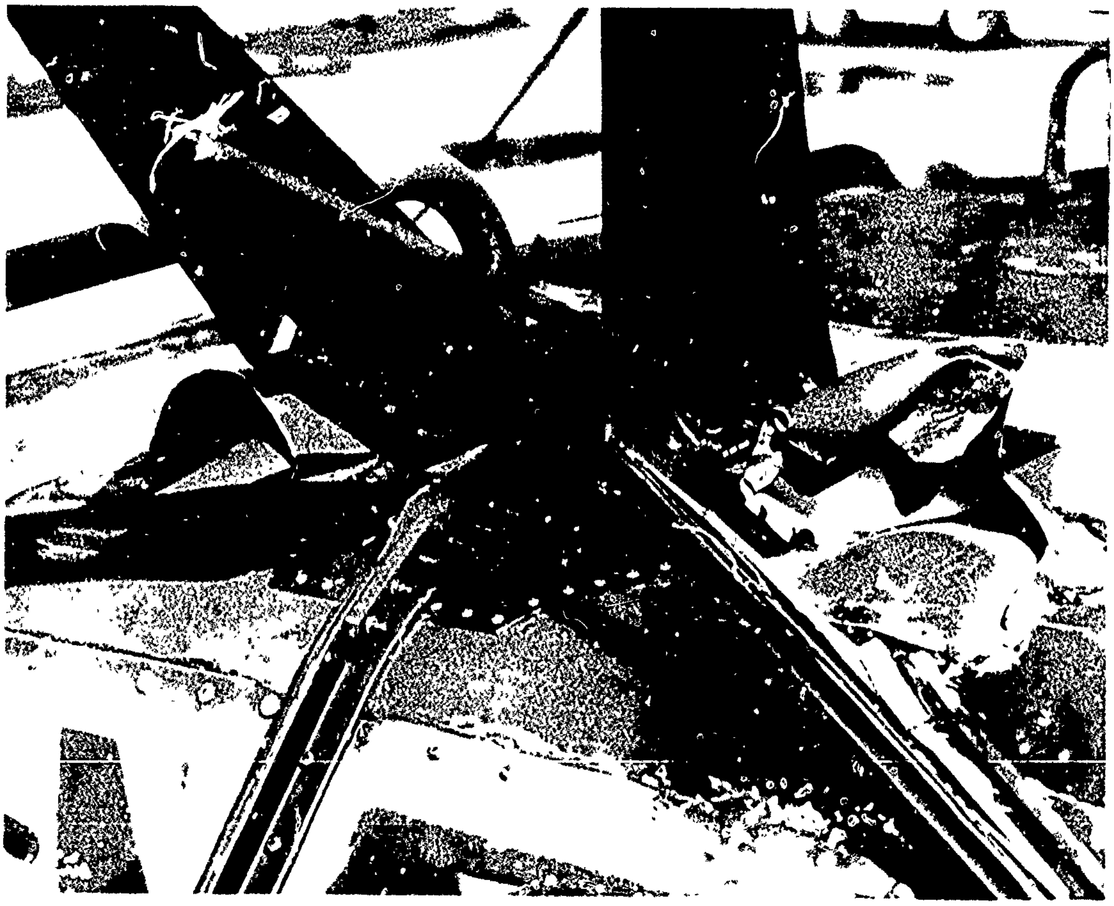

Figure 15. Aircraft damage from test 6.

ANALYSIS

Results of the tests show that the UH-1H WSPS, as modified, was effective in cutting the objective wire. There was no attempt to measure aircraft loads and attitude changes during the wire impact/deflection/cutting sequence, since these effects were found to be insignificant during earlier swing tests of the much lower mass OH-58A helicopter. UH-1H WSPS will not provide 100 percent protection from wire strike mishaps, since parts of the aircraft are not protected and since larger wires than the objective wire may present a problem, especially for the multiple wire strike situation. However, the passive UH-1H WSPS does provide a significant measure of protection from wire strike mishaps at a small weight penalty. The low weight and simplicity of the WSPS tested, coupled with its potential effectiveness, support the viability of application of wire strike protection to all Army helicopter systems, current and future. Consideration of a WSPS early in new aircraft design would result in a lower weight, less costly WSPS than would be possible with a retrofit system. The final UH-1H WSPS weight is 19.3 pounds, including all supporting structures.

CONCLUSIONS

1. The passive WSPS concept as modified and tested should be highly effective in protecting the UH-1 helicopter against mishaps caused by wire strikes. When the system is installed fleetwide, fewer accidents, injuries, and fatalities than are presently being experienced in unprotected Army helicopters should result.

2. Frame-by-frame film analysis indicates that the wire impact/deflection/cutting sequence will not have a significant effect on the helicopter or the operator with respect to performance and control.

3. The serrated blade insert in the windshield center-post deflector should be eliminated because it impedes deflection of the wire into the cutter and introduces excessive loads into the windshield and supporting structure.

RECOMMENDATIONS

Based on the ATL wire strike protection test series, it is recommended that:

1. The Army initiate retrofit of UH-1 helicopters with a WSPS.

2. All new helicopter specifications include a requirement for a WSPS.

3. The BLACK HAWK and Advanced Attack Helicopter Project Managers take action to define a WSPS configuration suitable for these helicopters, retrofit aircraft already produced, and plan for WSPS installation during production.