

**AIRCRAFT
ACCIDENT INVESTIGATION BOARD
REPORT**

**US ARMY UH-60
BLACK HAWK HELICOPTERS
87-26000 AND 88-26060**

VOLUME 7

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**AIRCRAFT
ACCIDENT INVESTIGATION BOARD
REPORT**

COPY

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OF

14

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F-15C 79-0025

O-4a

O-4a Maintenance Technical Report

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TECHNICAL REPORT F-15 MAINTENANCE

Aircraft Evaluated: F-15C, Tail Number 79-0025

Incident Date: 14 April 1994

I. INTRODUCTION: The purpose of this evaluation was to determine the air worthiness, capability and effectiveness of F-15C 79-0025's general aircraft and mission related systems.

II. BACKGROUND: The accident involved the crash of two US Army Black Hawk helicopters, serial numbers 88-26060 and 87-26000, and the possible involvement of US F-15 fighter aircraft, serial numbers 79-0025 and 84-0025, and a US AWACS, aircraft serial number 77-0351, in the crash of these helicopters in the northern No-Fly-Zone of Iraq on 14 April 1994.

Aircraft 79-0025 arrived at Incirlik AB on 23 February 1994 and had flown 31 sorties since its arrival, prior to the mishap sortie.

III. EVALUATION: The evaluation included a maintenance analysis of three areas: airframe (to include hydraulics systems, electrical systems, environmental control systems), engines, and avionics (to include fire control radar, communications, navigation, identification friend or foe (IFF), and air-to-air IFF interrogation (AAI) system). A review of the historical maintenance records for F-15C 79-0025 was completed for each system. This review included the current AFTO Form 781 aircraft maintenance records, aircraft historical records, and computerized equipment history for all three areas. In addition, engine historical records and engine oil analysis records were reviewed for both engines. The aircraft's weight and balance records were also reviewed.

Pilot testimony was reviewed for their assessment of the aircraft's general and mission related systems on the sortie prior to the mishap, the mishap sortie, and the sortie after the mishap sortie.

The optical clarity of the aircraft's canopy and windscreen was evaluated by an aircraft structural maintenance specialist in accordance with T.O. 1F-15C-3-4. (Atch 2)

Given the circumstances involved in the mishap, an extensive evaluation of the aircraft's AAI system was conducted. This evaluation is contained in a separate technical report at Tab O4b.

IV. DETERMINATION:

A. General Aircraft Systems:

Aircraft 79-0025 had accumulated 3650.0 airframe hours prior to the mishap sortie. (Tab H4a) On the mishap sortie, the aircraft had an open red diagonal (minor) pilot write-up for a counter measures dispenser (CMD) discrepancy (incorrect program loaded) and an informational pilot write-up for a radar Built-In-Test (BIT) light from the previous day's flight. The write-up on the radar BIT light went on to indicate there were no problems with the radar inflight. (Tab H4b) These discrepancies were not relevant to the mishap. Following the mishap sortie on 14 April

1994, the mishap pilot indicated the aircraft was Code 2 (minor discrepancy not affecting aircraft's combat capability) for radar. (Tab AC4g) The aircraft was flown on another sortie on 14 April 1994 after the mishap sortie. The pilot on that mission also indicated the aircraft as Code 2 for radar and also Code 2 for interior lights. (Tab AC4g)

A review of 79-0025's historical maintenance records revealed no indications of chronic maintenance problems on its airframe or engine systems over the past 30 days.

The aircraft's canopy and windscreen met all technical data requirements for optical clarity in accordance with T.O. 1F-15C-3-4. (Atch 2)

Aircraft 79-0025's computerized equipment review report and AFTO Forms 781 were reviewed for Time Compliance Technical Order (TCTO) compliance, scheduled inspection compliance, and component time change compliance. Aircraft 79-0025 had one overdue aircraft inspection (90 day aircraft wash and lubrication) but this was not relevant to the incident. (Tab H4c) There were no outstanding aircraft TCTOs that had exceeded their recission date. (Tab U4c)

The historical maintenance records of both engines were reviewed. Neither of the engines had any overdue scheduled engine inspections. (Tab H4d, H4e) Each engine had several outstanding engine TCTOs but none were beyond their grounding date and none were relevant to the incident. (Tab U4d)


The aircraft's oil analysis records for the past 10 sorties indicated normal readings (i.e. lab recommendation of code A). (Tab U4a)

B. Specific Mission Related Systems: A review of the historical maintenance forms indicates there were no communications, navigation, radar, or IFF discrepancies within the past 30 days that would have degraded mission effectiveness.

A review of pilot testimony indicated the aircraft's communications, navigation, radar, and IFF systems were operating normally during the mishap sortie. (Tab V28/Q192;Q195;Q197)

The AAI system analysis is contained in a separate technical report at Tab O4b.

C. Procedures: Maintenance personnel performed preflight and servicing on 79-0025 on 13 April 1994 at 1740L. Required preflight and servicing inspections were documented in the AFTO Forms 781H. (Tab H4a)


JEFFREY M. SNYDER, Major, USAF
F-15 Maint Board Member

2 Atchs

1. Statement of Certification
2. Affidavit - SSGT Thompson

STATEMENT OF CERTIFICATION

I am Major Jeff Snyder, assigned to the 48th Fighter Wing, RAF Lakenheath England as the squadron maintenance officer, 493rd Fighter Squadron. I am the F-15 maintenance board member on the AFR 110-14 Accident Board, investigating the crash of two US Army Black Hawk helicopters and the possible involvement of US fighter aircraft in the crash of these helicopters in the northern No-Fly Zone of Iraq on 14 Apr 94. I have held various positions as a F106 and F-15 maintenance officer, squadron commander, and logistics staff officer over the past 15 years. I have been a maintenance training squadron commander and equipment maintenance squadron commander. I served as Research Fellow at RAND Corporation and as Chief, Maintenance Plans and Policy Branch at HQ United States Air Forces in Europe. I received my Master's Degree in Logistics Management from the Air Force Institute of Technology. I have been associated with the F-15 since 1983.

Date: 5/16/94


JEFFREY M. SNYDER, Major, USAF
F-15 Maintenance Board Member

AFFIDAVIT
SSgt Norman P. Thompson
48th Equipment Maintenance Squadron
5 MAY 94

I have been a Structural Maintenance Technician, 2A773, for 11 1/2 years; out of those years I have worked F-15 for 5 years.

On 05 May 1994, I was asked to evaluate the canopy's and windshield's on Aircrafts: 9025, 4025. I used T.O. 1F-15C-3-4 to conduct this inspection. The criteria for the windshield can be found on page 4-16 para: 4-26B (Atch 1). The criteria for the canopy can be found on page 4-34A para 4-71e (Atch 2).

On my evaluation of A/C 9025 I found a scratch approximately 4 inches long at the 11 o'clock position on the windshield, near the windshield arch (Atch 3). Through visual inspection I found no distortion, and therefore there is no visual distortions. I then inspected the canopy, I found a few scratches that look like they may have come from a pilots helmet, but determined that they would be out of the pilots view area, and there was not any distortion.

I then inspected A/C 4025. Upon inspection I found a small distortion in the windshield at about 12:10 position. This was about half way down the windshield in the critical view area (Atch 4). I was not sure if it was a distortion or not so I examined the canopy and found the same thing I found on A/C 9025, and that was a few scratches but no distortions. I then went back and looked at the windshield again to make sure the distortion was still there and it was still there. Upon further inspection I determined that it was a small area not an area where a pilot would be able to focus in on for a long period of time.

Overall I found that both A/C's canopy's and windshield's were in very good condition. The canopy and windscreen are within limits IAW T.O. 1F-15C-3-4 on both aircraft.

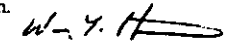
I swear or affirm that the information provided above is true and accurate and that I am the same Norman P Thompson who performed the inspections discussed above.



NORMAN P. THOMPSON, SSgt, USAF
Aircraft Structural Maint Technician

4 Atch

1. T.O. 1F-15C-3-4, p 4-16
2. T.O. 1F-15C-3-4, p 4-34A
3. T.O. 1F-15C-3-4, p 4-27
4. T.O. 1F-15C-3-4, p 4-27

CERTIFICATE	
I certify that I am the Records Custodian for the Accident Investigation Board convened to investigate the crash of two U.S. Army Black Hawk helicopters in the no fly zone in northern Iraq on 14 April 1994, and that this is a true and accurate copy of the record which is kept in my records system.	
<u>8 May 94</u> Date	 WILLIAM L. HARRIS, Capt, USAF, MSC Evidence Custodian, Incirlik Air Base, Turkey

Subscribed and sworn to before me this 5th day of May 1994.



Authority: 10 U.S.C. 1044a

4-23. **WINDSHIELD.** See figures 4-6 and 4-6A.

4-24. Two windshield assembly conditions exist for F-15 aircraft. The first condition uses the original 68A350002 windshield assembly. See figure 4-6. The second condition exists when the 68A350002 windshield assembly becomes damaged and needs to be replaced. Two spares kits, 68R310085 (F-15C) and 68R310087 (F-15D) may be used to replace the 68A350002 windshield assembly. See paragraph 4-59A for installation of spares kits. Each spares kit contains an F-15E improved bird strike resistant windshield assembly, 68A350016. See figure 4-6A. The 68A350002 and 68A350016 windshield assemblies are made up of a transparency, frames, frame substructure, and fairings. The windshield transparencies are stretched acrylic plastic.

4-25. **ACRYLIC TRANSPARENCY.** The 68A350002 windshield transparency is a single sheet of stretched acrylic plastic with phenolic fiberglass strips bonded to the edges where it attaches to the frames. See figure 4-6. The 68A350016 windshield transparency is a single sheet of stretched acrylic permanently bonded in the frames. See figure 4-6A.

CAUTION

Sealer applied to acrylic plastic on 68A350002 windshield assembly must have a noncraze accelerator to prevent damage.

NOTE

Be sure Protex 20 paper is overlapping at least 1/2 inch. The 2 inch masking tape is placed over the overlap area. At no time should the masking tape make contact with the acrylic transparency.

a. Acrylic surface should be covered on both sides using Protex 20 paper and 2-inch masking tape after rework is completed.

4-26. **Negligible Damage.** The damage limits below are classified as structurally negligible. The optics information is a guideline for allowable limits.

4-16 Change 53

a. Scratches, nicks, and gouges.

1. Critical vision area; see figures 4-6B and 4-7. Damage that does not positively cause hanging of a fingernail, length unlimited, provided:

(a) Damage can be reworked per paragraph 4-30, step a.

(b) Optics are acceptable per item b.

2. Noncritical vision area; see figures 4-6B and 4-7. Damage depth and length unlimited, provided:

(a) Damage can be reworked per paragraph 4-30.

(b) Transparency minimum thickness for 68A350002 windshield assembly after rework is 0.830 inch. Transparency minimum thickness for 68A350016 windshield assembly after rework is 0.900 inch. Refer to paragraph 4-27 for measuring transparency thickness.

(c) Optics are acceptable per item b.

b. Optics defects. Assuming the pilots normal flight position in the cockpit and viewing through the transparency against the sky and terrain, any defect that does not cause the viewer to focus on the defect, thereby causing distraction, is acceptable. Example: a defect in the critical vision area, see figures 4-6B and 4-7, would not be allowable; the same type defect outside of this area could be acceptable.

c. Phenolic fiberglass outer strip damage on 68A350002 windshield assembly. Delamination of the outer edging strips may occur as a result of wind, rain and/or hail erosion. The outer strips are added to provide a countersink surface for the flush attach bolts. Delamination may occur to the extent of removal of the strip down to the last lamination between fasteners with enough strip remaining under the countersink to make sure a tight fit exists for the bolts.

d. Minor distortions/streaks within the transparency spreading aft from the leading edge because of overheat from anti-ice hot air provided no fissures occur, fiberglass edging strips on 68A350002 windshield assembly are still

4-67. **CANOPY.** See figure 4-9 for F-15C and figure 4-11 for F-15D.

4-68. The F-15C and F-15D canopy consists of two transparencies spliced together, supported by frames, channels, and substructure, with fairings conforming to the aircraft mold line. The canopy has an inflatable seal for cockpit pressurization in addition to rain seals. The F-15C canopy has a pressure deck assembly integral to the canopy structure that covers the equipment bay. The canopy transparencies are stretched acrylic plastic. The acrylic plastic transparencies have the fiberglass edging strips set above the mold line.

4-69. **STRESS INTENSITY.** The stress intensities are divided into four classes: Class 1 area, very high; class 2 area, high; class 3 area, medium; and class 4 area, low. The aft fairing is class 4 area, low stress intensity and the web and pan are class 3 area, medium stress intensity.

4-70. **ACRYLIC TRANSPARENCIES.** Canopy transparencies are a single sheet stretched acrylic plastic with fiberglass edging strips bonded above the inner and outer mold line surfaces of transparencies. The edging strips mate with canopy structure.

CAUTION

Sealer applied to acrylic plastic must have a noncraze accelerator to prevent damage.

NOTE

Be sure Protex 20 paper is overlapping at least 1/2 inch. The 2 inch masking tape is placed over the overlap area. At no time should the masking tape make contact with the acrylic transparency.

a. Acrylic surface should be covered on both sides using Protex 20 paper and 2-inch masking tape after rework is complete.

4-71. **Negligible Damage.** The following damage limits are classified as structurally negligible. The

optics information is a guideline for acceptable criteria.

a. Nicks and gouges if no deeper than 0.020 and span out over an area no greater than 0.250 diameter.

b. Scratches no deeper than 0.020 and no longer than 8 inches.

c. Scuffs and helmet scrapes are acceptable.

d. All other nicks, scratches and gouges, unlimited in depth and length provided:

1. Transparency minimum thickness after rework is 0.300, except for:

(a) Localized damage where thickness may be reduced to 0.260 provided reworked area can be enclosed within a 2-inch diameter circle and spacings between such damages are a minimum of 4 inches, measured center to center.

(b) Leading edge damage from wind, rain or hail erosion, where leading edge thickness may be reduced to 0.260 provided damage can be blended per paragraph 4-73.

2. Optics are acceptable per item e.

e. Optics defects. Assuming the pilots normal flight position in the cockpit and/or rear cockpit, if applicable, and viewing through the transparency against the sky and terrain, any defect that does not cause the viewer to focus on the defect, thereby causing distraction, is acceptable.

EXAMPLE: A defect in the left or right vision area may be unacceptable; the same type defect elsewhere could be acceptable.

f. Phenolic fiberglass strip damage. Delamination of fiberglass strips may occur as a result of wind, rain or hail erosion. The strips are added to provide a countersink surface for the flush attach bolts. Delamination may occur to the extent of removal of the strip down to the last lamination between fasteners with enough remaining under the countersink to make sure a tight fit exists for the bolts. Delaminated and missing phenolic fiberglass strips may be repaired per paragraph 4-74B or 4-74F.

A/C 9025

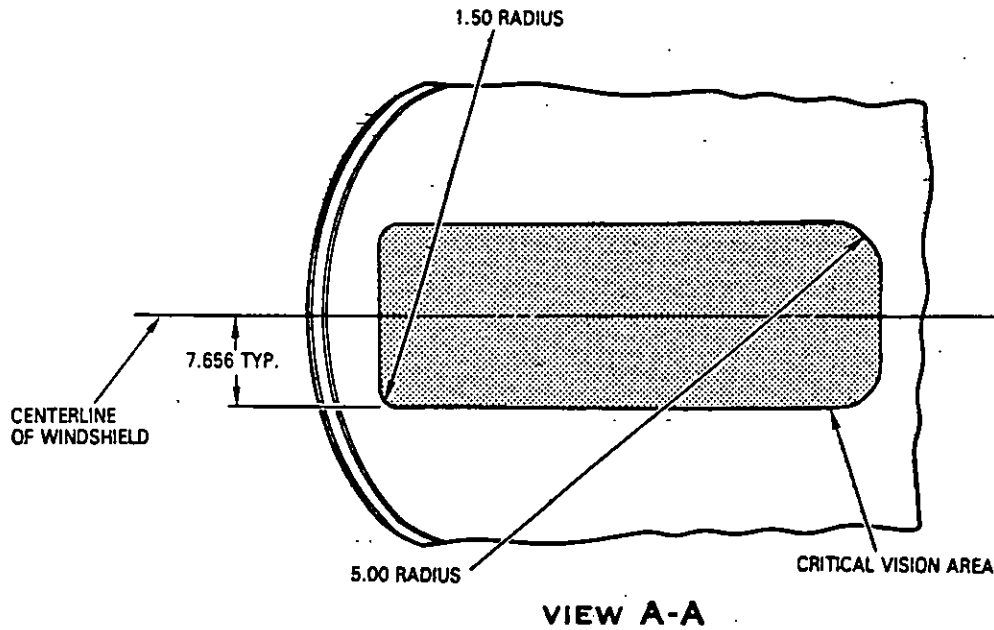
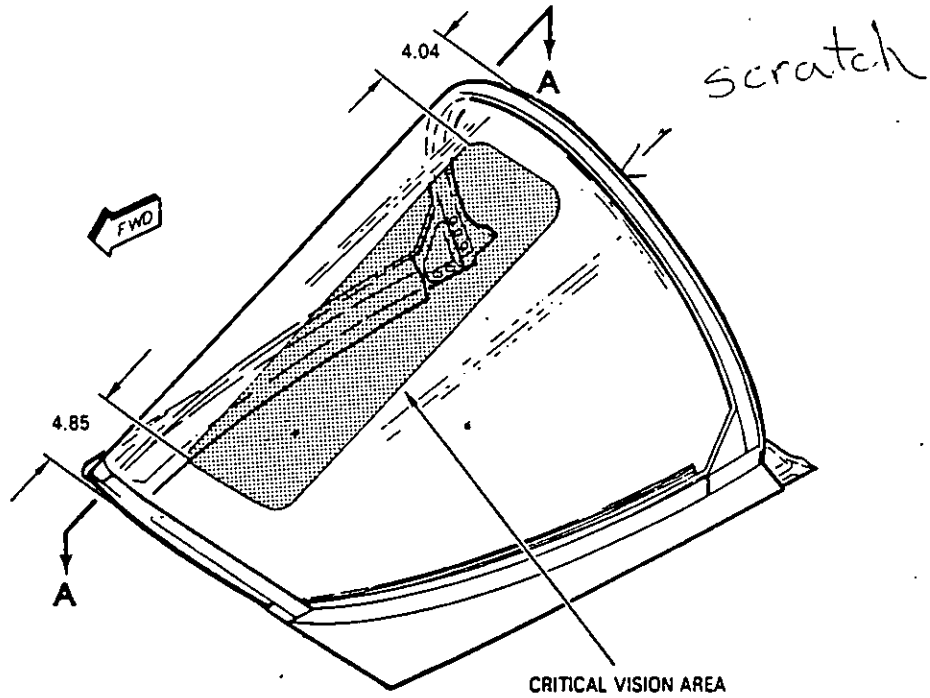
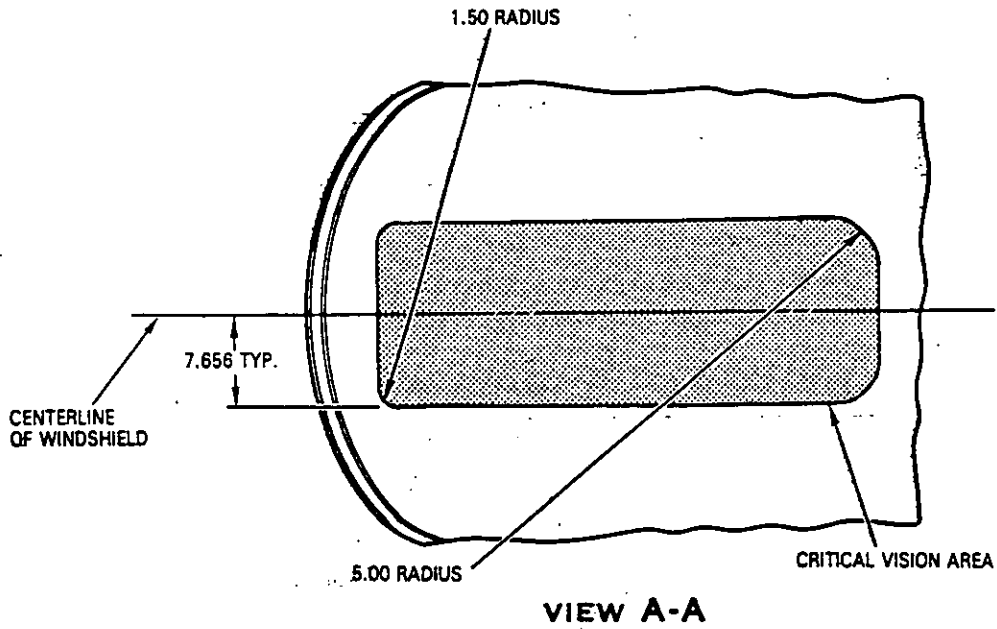
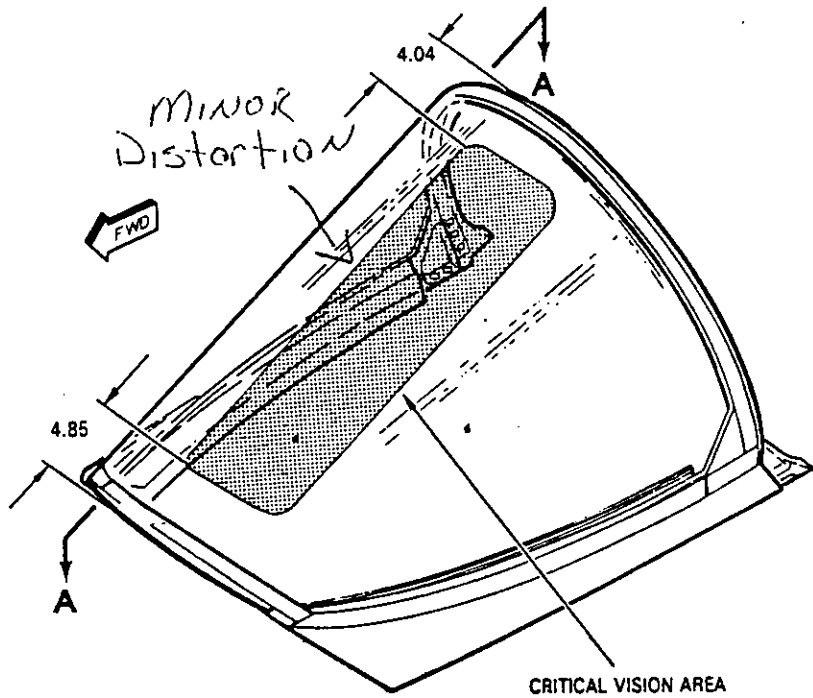


Figure 4-6B. Acrylic Transparency Rework Diagram, 68A350016

7-11



15C-3-4-(4.133)

Figure 4-6B. Acrylic Transparency Rework Diagram, 68A350016

TAB O-4

F-15C 79-0025

O-4a

O-4a Maintenance Technical Report

O-4b

O-4b IFF/AAI Technical Report

Technical Report

F-15 Air-to-Air Identification-Friend-or-Foe (IFF) Interrogation (AAI) System

Aircraft Evaluated: F-15C, Tail Number 79-0025

Incident Date: 14 April 1994

I. INTRODUCTION: The purpose of this evaluation was to determine the serviceability of F-15C 79-0025's AAI system.

II. BACKGROUND: The accident involved the crash of two US Army Black Hawk helicopters, serial numbers 88-26060 and 87-26000, and the possible involvement of US F-15 fighter aircraft, serial numbers 79-0025 and 84-0025, and a US AWACS, aircraft serial number 77-0351, in the crash of these helicopters in the northern No-Fly-Zone of Iraq on 14 April 1994.

Aircraft 79-0025 arrived at Incirlik AB on 23 February 1994 and had flown 31 sorties since its arrival, prior to the mishap sortie.

III. EVALUATION: A review of the historical maintenance records for F-15C 79-0025 was completed. This review included the current AFTO Form 781 aircraft maintenance records, aircraft historical records, and computerized equipment history. The purpose of the review was to identify any history of pilot reported discrepancies documented on the AAI system.

Pilot testimony to the board was also reviewed to determine their assessment of the aircraft's AAI system performance on the sortie prior to the mishap, the mishap sortie, and the sortie after the mishap sortie.

An F-15C maintenance technical advisor conducted a ground operational check of the aircraft's AAI system in accordance with Technical Order (T.O.) 1F15C-2-34JG-53-1. (Atch 2)

After completion of the ground check, the following components were removed from the aircraft and sent to Air Force teardown test facilities for detailed analysis:

Component	National Stock Number	Teardown Facility
AAI Interrogator Computer (KIR 1C)	5810-01-273-7819	AF Cryptological Support Center Kelly AFB, TX
AAI Receiver Transmitter (R/T)	5985-01-272-8047	Warner Robins Air Logistics Center Robins AFB, GA
IFF Reply Evaluator (IRE)	5985-01-016-2209	Warner Robins Air Logistics Center Robins AFB, GA

Interference Blanker 5865-01-114-2469

Warner Robins Air Logistics Center
Robins AFB, GA

AAI Cockpit Control Panel 5985-01-044-4987

Warner Robins Air Logistics Center
Robins AFB, GA

Specific maintenance procedures with possible relevance to the mishap were investigated. The 53rd Fighter Squadron's policies and procedures for loading Mode IV codes into the aircraft and for operationally checking the validity of those codes were reviewed and the squadron's adherence to those policies and procedures was evaluated.

IV. DETERMINATION:

A. BACKGROUND (The following information is derived from T.O. 1F-15C-2-34GS-00-1, dated 1 Apr 81, change 26, 15 Jul 93 and T.O. 1F15C-2-99GS-00-1, dated 1 May 91, change 4, 15 Aug 93)

The F-15C AAI system is an airborne IFF interrogator operating on Modes I, II, and III, plus a security mode (Mode IV). The system interrogator receives IFF replies from other aircraft, decodes them, then displays the appropriate symbology on the Vertical Situation Display (VSD) screen in the cockpit. The AAI system consists of an AAI control panel, a throttle multifunction switch, an IFF reply evaluator (IRE), an interrogator computer (KIR 1C/TSEC), 10 dipole antennas and an AAI receiver/transmitter (R/T).

The pilot initiates the interrogation process by moving the throttle multifunction switch to the left. This action sends the interrogate command to the radar system where it is processed and then sent on to the IRE for processing for use in the AAI system. At this time, the pilot will see an "I" displayed in the lower left corner of the VSD indicating that the interrogation process is in progress. The IRE produces an interrogation signal based on the requested mode (I, II, III, or IV) selected from the cockpit AAI control panel and sends this signal to the R/T unit. Additionally, if Mode IV is selected by the pilot, an interrogate command is routed from the IRE to the KIR 1C/TSEC interrogator computer which sends the current day's coded data back to the IRE to be included in the transmitted signal. The R/T unit transmits the interrogation signal through the AAI antennas that are mounted on the radar antenna.

The interrogation signal is received by an IFF transponder system in another aircraft which automatically sends back a coded return signal. This return signal is received through separate AAI antennas mounted on the radar antenna and is processed in the receiver portion of the R/T. The coded data is stripped from the received signal by the R/T, then sent to the IRE where the coded data is processed to determine its validity. For Mode IV interrogations, the reply portion of the return signal is routed to the KIR 1C/TSEC interrogator computer which interprets the reply for validity. A valid reply will trigger a Mode IV OK response to be sent back to the IRE. When a valid return signal is received, a signal is sent by the IRE to the radar telling it to display an AAI target return on the VSD. This signal is displayed on the VSD as either a circle or a diamond. The diamond symbology indicates a low confidence target and the circle symbology indicates a high confidence target. A low confidence target is one that has correctly replied to a

Mode I, II or III interrogation. A high confidence target is one that has correctly replied to a Mode IV interrogation.

The F-15C has an interference blanking system (IBS) whose purpose is to prevent interference between active aircraft systems on the same aircraft which would be brought about by multiple radio frequency transmitters and receivers. The only component of the IBS is the interference blanker. When a system on the F-15 is sending a signal through its receiver/transmitter, the interference blanker sends an electrical signal to other systems preventing them from inadvertently receiving that signal through their receiver/transmitters.

B. HISTORICAL RECORDS REVIEW

A review of the historical maintenance records for aircraft 79-0025 showed a 6 December 1993 writeup for the Mode IV portion of the AAI system completely inoperative. Maintenance technicians replaced the IFF reply evaluator and the AAI Built-in-Test checked good after the maintenance was completed. (Tab H4j) On 12 January, 1994, another write up was entered into the maintenance forms reporting the aircraft's Mode IV interrogator was malfunctioning. No Mode IV targets were displayed on the cockpit display and the Mode IV Built-in-Test failure light was illuminated during the Mode IV loop test. Maintenance replaced the IFF Reply Evaluator. (Tab H4k) The aircraft experienced an AAI failure in flight on both 24 and 25 February 1994. The AAI system was inoperative in all modes and codes according to pilot write-ups. Maintenance replaced the AAI R/T and the IRE on 25 February 1994, and the AAI system was confirmed as serviceable using ground test equipment. (Tab H4f) A pilot reported the Mode IV interrogator portion of the AAI system was inoperative in flight on 28 February 1994. Maintenance replaced the KIR 1A interrogator computer and the AAI system was confirmed as serviceable. (Tab H4g) There were no further documented AAI discrepancies between 28 February 94 and 14 April 94.

The aircraft was modified by TCTO 1229 on 9 March 1994, incorporating the new electronically keyed KIT 1C/TSEC transponder computer and KIR 1C/TSEC interrogator computer into the IFF and AAI system. (Tab U4b) These new components improve the reliability of loading the Mode IV codes into the aircraft's AAI and IFF systems.

C. PILOT ASSESSMENT

The pilot who flew aircraft 79-0025 on 13 April 1994 (the sortie prior to the mishap sortie) used the aircraft's AAI system to successfully interrogate the other F-15C in his flight with both Mode I and IV. (Tab V3b/p1 para5,6) The pilot of 79-0025 on the mishap sortie also used the aircraft's AAI system to successfully interrogate the other F-15C in his flight with both Mode I and IV. (Tab V28/Q13) The pilot on the mishap sortie also interrogated other aircraft enroute to the AOR (V28/Q13) The pilot of 79-0025 on the second sortie of 14 April (the sortie after the mishap sortie) used the aircraft's AAI system to successfully interrogate the other F-15C in his flight with both Mode I and IV. (Tab V62/Q54) He also successfully interrogated another aircraft on the way to the TAOR with Mode I and IV. (Tab V62/Q60)

D. FUNCTIONAL CHECK

A functional check of the aircraft's AAI system was conducted by an F-15 maintenance technical advisor on 20 and 21 April 1994. This test was performed using the AN/APM-349 Interrogation Systems Test Set. The test indicated the aircraft was capable of interrogating and displaying Modes I, II, and III low-confidence targets. However, the aircraft was not capable of displaying Mode IV high confidence targets. The test set had just been used on aircraft 84-0025 and had successfully exercised the Mode IV portion of the test set. The test set passed its self-test prior to the test of 79-0025's AAI system. Following prescribed F-15 troubleshooting steps outlined in the T.O. 1F-15C-2-34FI-00-2, the technical advisor removed and replaced the aircraft's IRE and the aircraft subsequently passed the Mode IV portion of the test. (Atch 2)

E. TEARDOWN ANALYSIS

The aircraft's IRE, AAI R/T, KIR 1C/TSEC, interference blanker, and AAI cockpit control panel were removed from the aircraft and sent for teardown analysis. The IFF R/T, interference blanker, AAI cockpit control panel, and IRE were sent to Warner Robins Air Logistics Center (WR ALC) and the KIR 1C/TSEC was sent to the Air Force Cryptologic Support Center, Kelly Air Force Base, Texas for teardown analysis.

The analysis of the IRE (serial number 0274) at WR ALC showed that, prior to the teardown, the unit met all functional test requirements. During teardown and individual circuit card testing, one circuit card had an out-of-tolerance test condition. Engineering analysis determined the discrepancy would have had no effect on the performance of the IRE. (Tab J4c)

The analysis of the AAI R/T (serial number CLT1203) at WR ALC indicated the unit was in good operating condition and met all critical test requirements. (Tab J4b)

The analysis of the KIR 1C/TSEC (serial number 01505) at the Air Force Cryptologic Support Center indicated the KIR 1C/TSEC passed all tests. (Tab J4a w/o attach)

The analysis of aircraft 79-0025's interference blanker (serial number 0650) at Warner Robins Air Logistics Center indicated this unit also met all functional test requirements. (Tab J4e)

The analysis of the AAI cockpit control panel (serial number 0729) at WR ALC indicated the unit passed all functional tests. (Tab J4d)

F. PROCEDURES:

KEYING MODE IV INTO THE AAI AND IFF SYSTEM PRIOR TO FLIGHT

The 53 Fighter Squadron (FS) maintenance organization enters the new day's Mode IV code into each of their aircraft's AAI and IFF system on the morning of the mission. (Tab V90/p2 para 4) This classified code is loaded into an electronic keyer (KYK-13). The electronic keyer is then used to key the IFF and AAI Mode IV systems. (Tab V90/p2 para 5) The Mode IV keying action is documented by a write-up in the aircraft forms binder.

The board received an inquiry from an individual employed by a company who printed

the technical data changes for the upgrade of the F-15 KIT 1A to the KIT 1C. The employee was concerned that the new technical data was not detailed enough for the procedure to load the Mode IV codes into the new KIT 1C. **(Tab V39/p2,para3)** An investigation showed the employee to be correct and the F-15 technical advisor has submitted a change to technical data (AFTO Form 22) to significantly expand the existing technical data. Although the technical data does not contain detailed information on loading Mode IV codes, it was determined that this technical data deficiency did not prevent the maintenance technicians from correctly loading the codes.

Aircraft 79-0025's IFF and AAI systems were keyed on the morning of 14 April 1994 **(Tab V90/p3 para2)** This action was properly documented in the aircraft forms binder. **(Tab H4-b)** The technician's training records indicate he was qualified to perform that task. **(Tab T6-a)**

CHECKOUT OF MODE IV PRIOR TO FLIGHT

The 53 FS maintenance policy, while deployed to Turkey, is to perform an operational check of each aircraft's IFF system just prior to takeoff on every Operation PROVIDE COMFORT mission. **(Tab V38/p1 para5)** An avionics technician, using an AN/APM-424 Transponder Test Set, interrogates each aircraft as it completes its end-of-runway check. **(Tab V40/p2 para 1)** If the aircraft properly replies to the interrogation, the avionics technician receives a green light in the tester and the pilot receives an audible tone, or a light, or both in the cockpit. **(Tab V40/p2 para 4)** This check confirms the correct Mode IV code was entered into the aircraft's IFF transponder computer (KIT 1C/TSEC). Since the Mode IV code is loaded simultaneously into the KIT 1C/TSEC and the AAI interrogator computer (KIR 1C/TSEC) **(Tab V90/p 2 para 4)**, this check also confirms the correct Mode IV code was loaded into the AAI system. It is squadron policy to ground abort an aircraft that does not pass this operational check of the IFF system. **(Tab V38/p2 para2)**

A squadron avionics technician interrogated aircraft 79-0025 using the -424 test set on the morning of 14 April 1994. The technician did not receive a green light in the IFF test set, but the pilot gave a "thumbs up" indicating he had received the proper cockpit indication. **(Tab V40/p 2 para 5)** The technician stated this was a known problem with this test set. **(Tab V40/p2 para4,5)** The technician's training records indicate he was in training for the operation of the IFF test set (i.e., training start date documented but training complete date not entered). **(Tab T6-b)** An F-15 maintenance technical advisor evaluated this technician on the operation of the IFF test set, on 28 April 1994, and found him to be proficient in its use. **(Atch 3)**

3 Attach

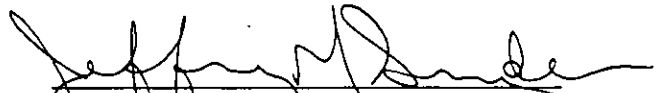
1. Statement of certification
2. F-15 Technical Advisor's report
w/o attachments
3. F-15 Technical Advisor's memo


JEFFREY M. SNYDER, Maj, USAF
F-15 Maintenance Board Member

STATEMENT OF CERTIFICATION

I am Major Jeff Snyder, assigned to the 48th Fighter Wing, RAF Lakenheath England as the squadron maintenance officer, 493rd Fighter Squadron. I am the F-15 maintenance board member on the AFR 110-14 Accident Board, investigating the crash of two US Army Black Hawk helicopters and the possible involvement of US fighter aircraft in the crash of these helicopters in the northern No-Fly Zone of Iraq on 14 Apr 94. I have held various positions as a F106 and F-15 maintenance officer, squadron commander, and logistics staff officer over the past 15 years. I have been a maintenance training squadron commander and equipment maintenance squadron commander. I served as Research Fellow at RAND Corporation and as Chief, Maintenance Plans and Policy Branch at HQ United States Air Forces in Europe. I received my Master's Degree in Logistics Management from the Air Force Institute of Technology. I have been associated with the F-15 since 1983.

Date: 16 May 94


JEFFREY M. SNYDER, Major, USAF
F-15 Maintenance Board Member

REPORT
ON
AIR-TO-AIR IFF INTERROGATOR (AAI)
SYSTEM
OPERATIONAL CHECKOUT
F-15C 79-0025
CONDUCTED 20/21 APRIL 1994
BY
GERALD D SILVIUS, GS-11
F-15 MAINTENANCE TECHNICAL ADVISOR

CERTIFICATE

I certify that I am the Records Custodian for the Accident Investigation Board convened to investigate the crash of two U.S. Army Black Hawk helicopters in the no fly zone in northern Iraq on 14 April 1994, and that this is a true and accurate copy of the record which is kept in my records system.

J.M. 74
Date

W.L.H.
WILLIAM L. HARRIS, Capt, USAF, MSC
Evidence Custodian, Incirlik Air Base, Turkey

Attachee W.L.H. - with

PREFACE

This is a brief explanation of terms that will be used in the following description of the maintenance testing of F-15C aircraft tail numbers 840025 and 790025.

VSD Vertical Situation Display

BIT Built in Test

IFF Identification Friend-or-Foe transponder system. The IFF transponder system does the self-identification function for the aircraft. The system receives challenging signals (interrogations), determines authenticity and mode of challenge, and automatically transmits coded replies. The system operates in Modes I, II, and III/A, which are Selective Identification Feature (SIF) modes, plus security Mode IV.

AAI Air-to-Air IFF Interrogator system. The AAI system is an airborne IFF interrogator, independent of the IFF transponder, operating on the standard SIF feature Modes I, II, and III, plus Mode IV. The system transmits challenge signals and receives replies through antennas mounted on the radar antenna. The system decodes IFF replies to develop a confidence level display correlated with radar targets of the radar VSD.

AAI A built in test used to determine the serviceability of the AAI interrogator system,
BIT exclusive of the Mode IV BIT test. Can be initiated by maintenance personnel or aircrew.

Loop Mode IV initiated BIT. An initiated BIT check that enables the maintenance
Check technician to check the Mode IV serviceability of the IFF and the AAI systems. The BIT circuitry enables the on board AAI system to interrogate the on board IFF system, giving go/nogo indications to the technician.

424 Transponder Set Test Set, AN/APM-424. A small, hand held test set that provides a
Tester complete checkout of all IFF transponder features, including Mode IV. The test set interrogates the aircraft IFF system, receives the coded replies, determines the authenticity of the replies and displays the result as a go/nogo display to the operator.

349
Tester

Interrogator Systems Test Set, AN/APM-349. A flightline test set that provides a checkout of all aircraft AAI system modes, including Mode IV. The test set acts as an IFF transponder that automatically transmits replies to aircraft interrogations in SIF modes I, II, III, and Mode IV. During the interrogation test, the tester displays an accept light for proper aircraft interrogations and the aircraft will display an applicable low or high confidence target on the VSD. SIF mode targets will be displayed as low confidence targets and Mode IV targets as high confidence targets.

AIRCRAFT 790025
20 APRIL 1994

Opened up the aircraft panels and visually inspected the AAI/IFF systems for serviceability. The components all appeared to be in good condition. A visual inspection of cockpit revealed the following control switch positions: AAI Mode select switch was set to 4A, the code wheels were set to 0000. The IFF Mode IV switch was set to "A", the IFF Mode I code was 43, the IFF Mode III/A code wheels were set to 2400, IFF Mode I switch was set to ON, the IFF Mode II switch was set to OUT, and the IFF Mode III/A switch was set to OUT.

The units installed in the aircraft were as follows; AAI Receiver/Transmitter (R/T), Radio, RT868C/APX-76(V), serial number CLT 1203. AAI Radar Target Data Processor, MX9147A/APX, serial number 0247. KIR-1C/TSEC Interrogator Computer serial number 01505. The Receiver/Transmitter (R/T) has a slightly different part number than the one contained in aircraft 840025; RT868C/APX-76(V) versus RT868D/APX-76(V). Research of T.O. 1F-15C-4-4, figure 71, index 42, reveals that both R/T's are authorized for use in this aircraft (Atch. 2).

Performed the safe for maintenance checks, power on checks, attached ground equipment to the aircraft, and applied power to the aircraft. The 349 tester that was used during this checkout was 16 days past due calibration. The decision was made to proceed, in order to get an indication of the AAI system serviceability. Applied power to the 349 tester, serial number DGX-86, and ran the self checks successfully.

The first check to be accomplished was the AAI BIT check IAW T.O. 1F-15C-2-34JG-53-1 (Atch. 1). After system warm up, the BIT check failed with a receiver fail fault shown on the R/T. Turned the AAI system off and back to on, recycling the power, and the BIT check passed after the warm-up period. Ran 5 more successful BIT checks at this time.

The next check to be accomplished was the Mode IV Loop Check IAW T.O. 1F-15C-2-34JG-53-1 (Atch. 1). Performed 6 successful Loop Checks giving the correct cockpit indications each time.

The next check accomplished was the AAI operational checkout using the 349 tester IAW T.O. 1F-15C-2-34JG-53-1 (Atch. 1). The steps listed are the actual operational testing after the set-up procedure;

STEP	MODE	RESULTS
29-31	M-III	The aircraft successfully interrogated the 349 tester displaying the interrogation cue, however, the aircraft only displayed the low confidence target on the VSD 3 of 6 interrogations. The 349 tester showed a hard reject light.
32	M-III	A second Mode III test with a different code set into the control head. The results were the same as the previous test, intermittent target display and hard reject light on the 349 tester. Interrogated 6 times.
33-40	M-II	The aircraft displayed the interrogate cue on the VSD and displayed the low confidence target at the proper range, the 349 tester reject light was illuminated. Interrogated 6 times.
41-44	M-I	The aircraft displayed the interrogate cue on the VSD but only one low confidence target reply in 6 attempts, the 349 tester reject light was illuminated.
45-57	M-IV	The aircraft displayed the interrogate cue and never displayed a high confidence target on either Mode IV A or B codes. Had a hard reject light on the 349 tester continuously. Interrogated Mode IV A and B 6 times each.

AIRCRAFT 790025
21 APRIL 1994

Using 349 tester serial number DGX-59, the entire testing procedure was performed again. Performed the safe for maintenance checks, power on checks, attached ground equipment to the aircraft, and applied power. Applied power to the 349 tester, ran the self checks which passed.

The first check to be accomplished was the AAI BIT check IAW T.O. 1F-15C-2-34JG-53-1 (Atch. 1). At initial turn on of the AAI, after the warm up period, ran the BIT check which failed badly. The BIT light did not flash and there were no low confidence targets displayed on the VSD. Attempted to run additional BIT checks and the system degraded further. Turned the system off and back to on to let the power recycle, after the time in period the BIT check ran without a problem. Ran the BIT check 5 more times with good results.

The next check to be accomplished was the Mode IV Loop Check IAW T.O. 1F-15C-2-34JG-53-1 (Atch. 1). The Loop Check passed giving all good indications. Loop Check was ran successfully 6 times.

The next check accomplished was the AAI operational checkout using the 349 tester IAW T.O. 1F-15C-2-34JG-53-1 (Atch. 1). The steps listed are the actual operational testing after the set-up procedure;


STEP	MODE	RESULTS
29-31	M-III	The aircraft successfully interrogated the 349 tester displaying the interrogation cue and a low confidence target at the proper range on the VSD. The 349 accept light illuminated indicating that the interrogations were correct. Interrogated the tester 6 times with the same result.
32	M-III	A second Mode III test with a different code set into the control head. The aircraft display was correct and the accept light illuminated on the 349 tester. Interrogated 6 times successfully.
33-40	M-II	The aircraft displayed the interrogate cue on the VSD and a low confidence target at the proper range. The 349 tester accept light was illuminated. Interrogated 6 times successfully.
41-44	M-I	The aircraft displayed the interrogate cue on the VSD and a low confidence target at the proper range. The 349 tester accept light was illuminated. Interrogated 6 times successfully.

45-57 M-IV The aircraft never displayed a high confidence target on either Mode IV code, A or B. The 349 tester displayed an accept light indicating that the AAI was interrogating with the correct codes, but no targets were displayed. The Job Guide Fault Code for this problem is 3453G3ZZ (Atch. 1). The troubleshooting guide for this fault code in T.O. 1F-15C-2-34FI-00-2 (Atch. 3) indicates that the Radar Target Data Processor could be the faulty unit. Considering the previous BIT problems encountered, I decided to install a replacement unit, serial number 1163. Performed the 349 checks again and the aircraft displayed a high confidence target at the proper range on the VSD for both Mode IV A and B codes. This check ran successfully 5 times each for the A code and the B code. The replacement unit was removed and returned serviceable.

To further prove the overall AAI/IFF system reliability a 424 tester was used to interrogate the IFF system separately to determine if it had a problem. The 424 tests passed five times in succession indicating that the IFF system was operational.

CONCLUSION

At the time of the operational checks, the AAI system installed in aircraft 790025 was capable of interrogating Modes I, II, and III, plus Mode IV, was also capable of displaying Modes I, II, and III low confidence targets but was not capable of displaying Mode IV high confidence targets with Radar Target Data Processor serial number 0274 installed.


Gerald D. Silvius, GS-11, DAF
F-15 Technical Advisor

3 Attachments: *withheld*

~~1. Excerpts from TO 1F-15C-2-34JG-53-1~~

~~2. Excerpts from TO 1F-15C-4-4~~


~~3. Excerpts from TO 1F-15C-2-34FI-00-2~~


Memorandum for Record

30 April 1994

TO: Whom it May Concern

At Major Snyder's request, on the morning of 28 April, I observed Airman Norman interrogate the Identification Friend-or-Foe systems on two 53 FS F-15C aircraft with the AN/MPM-424 test set. The interrogation was being performed on the aircraft as they were stopped on the taxi way adjacent to the 53 FS parking area as required by 53 FS policy for mode 4 checks prior to flight at OPC. He performed step 4 of the test set self test procedure and step 40 of the mode 4 test as shown in TO 1F-15C-2-34JG-52-1 correctly on both aircraft. Successful completion of these steps satisfies the requirement for the prior to flight mode 4 check.


Gerald D. Silvius, GS-11, DAF
F-15 Technical Advisor

CERTIFICATE	
I certify that I am the Records Custodian for the Accident Investigation Board convened to investigate the crash of two U.S. Army Black Hawk helicopters in the no fly zone in northern Iraq on 14 April 1994, and that this is a true and accurate copy of the record which is kept in my records system.	
<u>7 May 94</u> Date	 WILLIAM L. HARRIS, Capt, USAF, MSC Evidence Custodian, Incirlik Air Base, Turkey

TAB O

ADDITIONAL SUBSTANTIATING DATA REPORTS

	O-1
	O-2
O-1 UH-60 Black Hawk 88-26060	O-3
O-2 UH-60 Black Hawk 87-26000	O-4
O-3 E-3B AWACS	O-5
O-4 F-15C 79-0025	
O-5 F-15C 84-0025	
O-6 Human Factors	
O-7 Medical Reports	
O-8 Optics Report	
O-9 Crash Site Analysis Technical Report	
O-10 Technical Report, F-15C IFF/AAI Systems (See also Classified Addendum)	
O-11 Technical Report UH-60 Black Hawk IFF/AAI Systems	

TAB O-5

F-15C 84-0025

O-5a

O-5a Maintenance Technical Report

O-5b IFF/AAI Technical Report

TECHNICAL REPORT F-15 MAINTENANCE

Aircraft Evaluated: F-15C, Tail Number 84-0025

Incident Date: 14 April 1994

I. INTRODUCTION: The purpose of this evaluation was to determine the air worthiness, capability and effectiveness of F-15C 84-0025's general aircraft and mission related systems.

II. BACKGROUND: The accident involved the crash of two US Army Black Hawk helicopters, serial numbers 88-26060 and 87-26000, and the possible involvement of US F-15 fighter aircraft, serial numbers 79-0025 and 84-0025, and a US AWACS, aircraft serial number 77-0351, in the crash of these helicopters in the northern No-Fly-Zone of Iraq on 14 April 1994.

Aircraft 84-0025 arrived at Incirlik AB on 6 April 1994 and had flown 9 sorties since its arrival, prior to the incident sortie.

III. EVALUATION: The evaluation included a maintenance analysis of three areas: airframe (to include hydraulics systems, electrical systems, and environmental control systems), engines, and avionics (to include fire control radar, communications, navigation, identification friend or foe (IFF), and air-to-air IFF interrogation (AAI) system). A review of the historical maintenance records for F-15C 84-0025 was completed for each system. This review included the current AFTO Form 781 aircraft maintenance records, aircraft historical records, and computerized equipment history for all three areas. In addition, engine historical records and engine oil analysis records were reviewed for both engines. The aircraft's weight and balance records were also reviewed.

Pilot testimony was reviewed for their assessment of the aircraft's general and mission related systems on the sortie prior to the mishap, the mishap sortie, and the sortie after the mishap sortie.

The optical clarity of the aircraft's canopy and windscreen was evaluated by an aircraft structural maintenance specialist in accordance with T.O. 1F-15C-3-4. (Atch 2)

Given the circumstances involved in the mishap, an extensive evaluation of the aircraft's AAI system was conducted. This evaluation is contained in a separate technical report at Tab O5b.

IV. DETERMINATION:

A. General Aircraft Systems:

Aircraft 84-0025 had accumulated 2990.0 airframe hours prior to the mishap sortie (Tab H5a). Following the mishap sortie on 14 April 1994, the mishap pilot indicated the aircraft was a Code 1 aircraft (i.e., no discrepancies). (Tab AC4g) The aircraft was flown on another sortie after the mishap sortie on 14 April 1994, and the pilot on that mission also indicated the aircraft was Code 1. (Tab AC4g)

A review of 84-0025's historical maintenance records revealed no indications of chronic maintenance problems on its airframe or engine systems over the past 30 days.

The aircraft's canopy and windscreen met all technical data requirements for optical clarity in accordance with T.O. 1F-15C-3-4. **(Atch 2)**

Aircraft 84-0025's computerized equipment review report and AFTO Forms 781 were reviewed for Time Compliance Technical Order (TCTO) compliance, scheduled inspection compliance, and component time change compliance. The aircraft had just completed a scheduled (every 200 flying hours) aircraft inspection. **(Tab H5c)** The AFTO Form 781K revealed the aircraft had two overdue aircraft inspections (90 day aircraft wash and 14 day document review). None of these discrepancies were relevant to the incident. **(Tab H5c)** There were no outstanding aircraft TCTOs that had exceeded their grounding dates and none were relevant to the incident. **(Tab U5c)**

The historical maintenance records of both engines were reviewed. Neither of the engines had any overdue scheduled engine inspections. **(Tab H5d, H5e)** Each engine had several outstanding engine TCTOs, but none were beyond the grounding date, and none were relevant to the incident. **(Tab U5d)**

The aircraft's oil analysis records for the past 10 sorties indicated normal readings (i.e. lab recommendation of code A). **(Tab U5a)**

B. Specific Mission Related Systems: A review of the aircraft's historical maintenance forms indicate there were no communications, navigation, radar, or IFF discrepancies within the past 30 days that would have degraded mission effectiveness.

A review of pilot testimony indicated the aircraft's communications, navigation, radar, and IFF systems were operating normally during the mishap sortie. **(Tab V29/Q156;Q158;Q159;Q164)**

The AAI system analysis is contained in a separate technical report at Tab O5b.

C. Procedures: Maintenance personnel performed preflight and servicing on 84-0025 on 13 April 1994 at 1700L. Preflight and servicing inspections were documented in the AFTO Forms 781H. **(Tab H5a)**


JEFFREY M. SNYDER, Major, USAF
F-15 Maintenance Board Member

2 Atchs

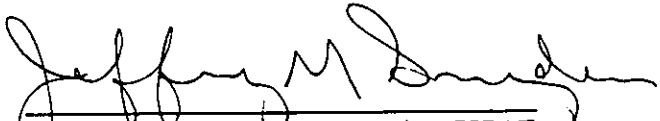
1. Statement of Certification
2. Affidavit - SSGT Thompson

STATEMENT OF CERTIFICATION

I am Major Jeff Snyder, assigned to the 48th Fighter Wing, RAF Lakenheath England as the squadron maintenance officer, 493rd Fighter Squadron. I am the F-15 maintenance board member on the AFR 110-14 Accident Board, investigating the crash of two US Army Black Hawk helicopters and the possible involvement of US fighter aircraft in the crash of these helicopters in the northern No-Fly Zone of Iraq on 14 Apr 94. I have held various positions as a F106 and F-15 maintenance officer, squadron commander, and logistics staff officer over the past 15 years. I have been a maintenance training squadron commander and equipment maintenance squadron commander. I served as Research Fellow at RAND Corporation and as Chief, Maintenance Plans and Policy Branch at HQ United States Air Forces in Europe. I received my Master's Degree in Logistics Management from the Air Force Institute of Technology. I have been associated with the F-15 since 1983.

Date: _____

5/16/94



JEFFREY M. SNYDER, Major, USAF
F-15 Maintenance Board Member

AFFIDAVIT

SSgt Norman P. Thompson
48th Equipment Maintenance Squadron
5 MAY 94

I have been a Structural Maintenance Technician, 2A773, for 11 1/2 years; out of those years I have worked F-15 for 5 years.

On 05 May 1994, I was asked to evaluate the canopy's and windshield's on Aircrafts: 9025, 4025. I used T.O. 1F-15C-3-4 to conduct this inspection. The criteria for the windshield can be found on page 4-16 para: 4-26B (Atch 1). The criteria for the canopy can be found on page 4-34A para 4-71e (Atch 2).

On my evaluation of A/C 9025 I found a scratch approximately 4 inches long at the 11 o'clock position on the windshield, near the windshield arch (Atch 3). Through visual inspection I found no distortion, and therefore there is no visual distortions. I then inspected the canopy, I found a few scratches that look like they may have come from a pilots helmet, but determined that they would be out of the pilots view area, and there was not any distortion.

I then inspected A/C 4025. Upon inspection I found a small distortion in the windshield at about 12:10 position. This was about half way down the windshield in the critical view area (Atch 4). I was not sure if it was a distortion or not so I examined the canopy and found the same thing I found on A/C 9025, and that was a few scratches but no distortions. I then went back and looked at the windshield again to make sure the distortion was still there and it was still there. Upon further inspection I determined that it was a small area not an area where a pilot would be able to focus in on for a long period of time.

Overall I found that both A/C's canopy's and windshield's were in very good condition. The canopy and windscreen are within limits IAW T.O. 1F-15C-3-4 on both aircraft.

I swear or affirm that the information provided above is true and accurate and that I am the same Norman P Thompson who performed the inspections discussed above.

Norman P Thompson

NORMAN P. THOMPSON, SSgt, USAF
Aircraft Structural Maint Technician

4 Atch

1. T.O. 1F-15C-3-4, p 4-16
2. T.O. 1F-15C-3-4, p 4-34A
3. T.O. 1F-15C-3-4, p 4-27
4. T.O. 1F-15C-3-4, p 4-27

CERTIFICATE

I certify that I am the Records Custodian for the Accident Investigation Board convened to investigate the crash of two U.S. Army Black Hawk helicopters in the no fly zone in northern Iraq on 14 April 1994, and that this is a true and accurate copy of the record which is kept in my records system.

8 May 94
Date

W. L. Harris
WILLIAM L. HARRIS, Capt, USAF, MSC
Evidence Custodian, Incirlik Air Base, Turkey

Subscribed and sworn to before me this 5th day of May 1994.

Stan A. Stahl

4-23. **WINDSHIELD.** See figures 4-6 and 4-6A.

4-24. Two windshield assembly conditions exist for F-15 aircraft. The first condition uses the original 68A350002 windshield assembly. See figure 4-6. The second condition exists when the 68A350002 windshield assembly becomes damaged and needs to be replaced. Two spares kits, 68R310085 (F-15C) and 68R310087 (F-15D) may be used to replace the 68A350002 windshield assembly. See paragraph 4-59A for installation of spares kits. Each spares kit contains an F-15E improved bird strike resistant windshield assembly, 68A350016. See figure 4-6A. The 68A350002 and 68A350016 windshield assemblies are made up of a transparency, frames, frame substructure, and fairings. The windshield transparencies are stretched acrylic plastic.

4-25. **ACRYLIC TRANSPARENCY.** The 68A350002 windshield transparency is a single sheet of stretched acrylic plastic with phenolic fiberglass strips bonded to the edges where it attaches to the frames. See figure 4-6. The 68A350016 windshield transparency is a single sheet of stretched acrylic permanently bonded in the frames. See figure 4-6A.



Sealer applied to acrylic plastic on 68A350002 windshield assembly must have a noncraze accelerator to prevent damage.

NOTE

Be sure Protex 20 paper is overlapping at least 1/2 inch. The 2 inch masking tape is placed over the overlap area. At no time should the masking tape make contact with the acrylic transparency.

a. Acrylic surface should be covered on both sides using Protex 20 paper and 2-inch masking tape after rework is completed.

4-26. **Negligible Damage.** The damage limits below are classified as structurally negligible. The optics information is a guideline for allowable limits.

a. Scratches, nicks, and gouges.

1. Critical vision area; see figures 4-6B and 4-7. Damage that does not positively cause hanging of a fingernail, length unlimited, provided:

(a) Damage can be reworked per paragraph 4-30, step a.

(b) Optics are acceptable per item b.

2. Noncritical vision area; see figures 4-6B and 4-7. Damage depth and length unlimited, provided:

(a) Damage can be reworked per paragraph 4-30.

(b) Transparency minimum thickness for 68A350002 windshield assembly after rework is 0.830 inch. Transparency minimum thickness for 68A350016 windshield assembly after rework is 0.900 inch. Refer to paragraph 4-27 for measuring transparency thickness.

(c) Optics are acceptable per item b.

b. Optics defects. Assuming the pilots normal flight position in the cockpit and viewing through the transparency against the sky and terrain, any defect that does not cause the viewer to focus on the defect, thereby causing distraction, is acceptable. Example: a defect in the critical vision area, see figures 4-6B and 4-7, would not be allowable; the same type defect outside of this area could be acceptable.

c. Phenolic fiberglass outer strip damage on 68A350002 windshield assembly. Delamination of the outer edging strips may occur as a result of wind, rain and/or hail erosion. The outer strips are added to provide a countersink surface for the flush attach bolts. Delamination may occur to the extent of removal of the strip down to the last lamination between fasteners with enough strip remaining under the countersink to make sure a tight fit exists for the bolts.

d. Minor distortions/streaks within the transparency spreading aft from the leading edge because of overheat from anti-ice hot air provided no fissures occur, fiberglass edging strips on 68A350002 windshield assembly are still

4-67. **CANOPY.** See figure 4-9 for F-15C and figure 4-11 for F-15D.

4-68. The F-15C and F-15D canopy consists of two transparencies spliced together, supported by frames, channels, and substructure, with fairings conforming to the aircraft mold line. The canopy has an inflatable seal for cockpit pressurization in addition to rain seals. The F-15C canopy has a pressure deck assembly integral to the canopy structure that covers the equipment bay. The canopy transparencies are stretched acrylic plastic. The acrylic plastic transparencies have the fiberglass edging strips set above the mold line.

4-69. **STRESS INTENSITY.** The stress intensities are divided into four classes: Class 1 area, very high; class 2 area, high; class 3 area, medium; and class 4 area, low. The aft fairing is class 4 area, low stress intensity and the web and pan are class 3 area, medium stress intensity.

4-70. **ACRYLIC TRANSPARENCIES.** Canopy transparencies are a single sheet stretched acrylic plastic with fiberglass edging strips bonded above the inner and outer mold line surfaces of transparencies. The edging strips mate with canopy structure.

CAUTION

Sealer applied to acrylic plastic must have a noncraze accelerator to prevent damage.

NOTE

Be sure Protex 20 paper is overlapping at least 1/2 inch. The 2 inch masking tape is placed over the overlap area. At no time should the masking tape make contact with the acrylic transparency.

a. Acrylic surface should be covered on both sides using Protex 20 paper and 2-inch masking tape after rework is complete.

4-71. **Negligible Damage.** The following damage limits are classified as structurally negligible. The

optics information is a guideline for acceptable criteria.

a. Nicks and gouges if no deeper than 0.020 and span out over an area no greater than 0.250 diameter.

b. Scratches no deeper than 0.020 and no longer than 8 inches.

c. Scuffs and helmet scrapes are acceptable.

d. All other nicks, scratches and gouges, unlimited in depth and length provided:

1. Transparency minimum thickness after rework is 0.300, except for:

(a) Localized damage where thickness may be reduced to 0.260 provided reworked area can be enclosed within a 2-inch diameter circle and spacings between such damages are a minimum of 4 inches, measured center to center.

(b) Leading edge damage from wind, rain or hail erosion, where leading edge thickness may be reduced to 0.260 provided damage can be blended per paragraph 4-73.

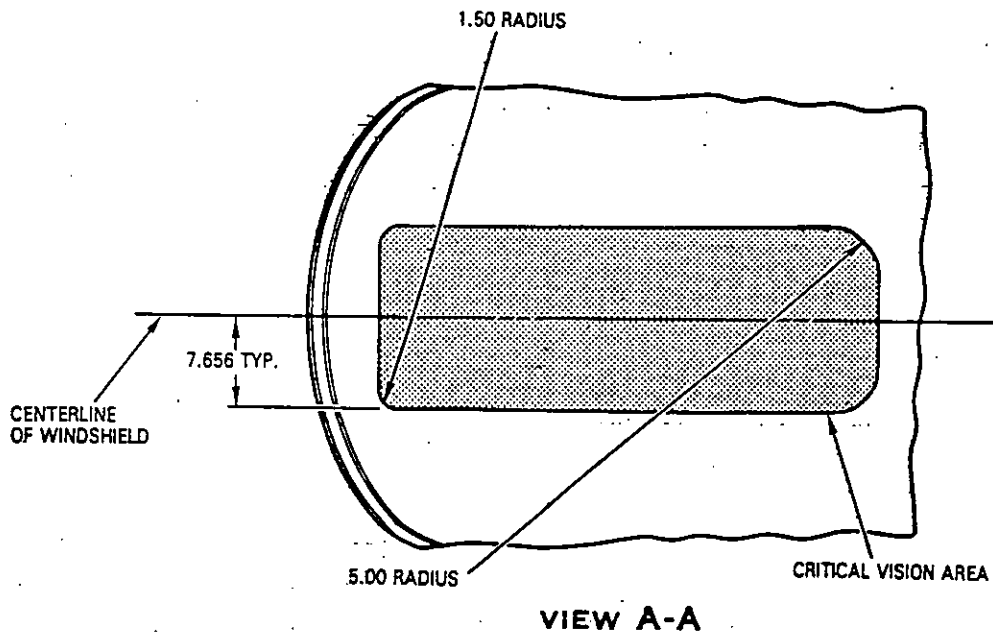
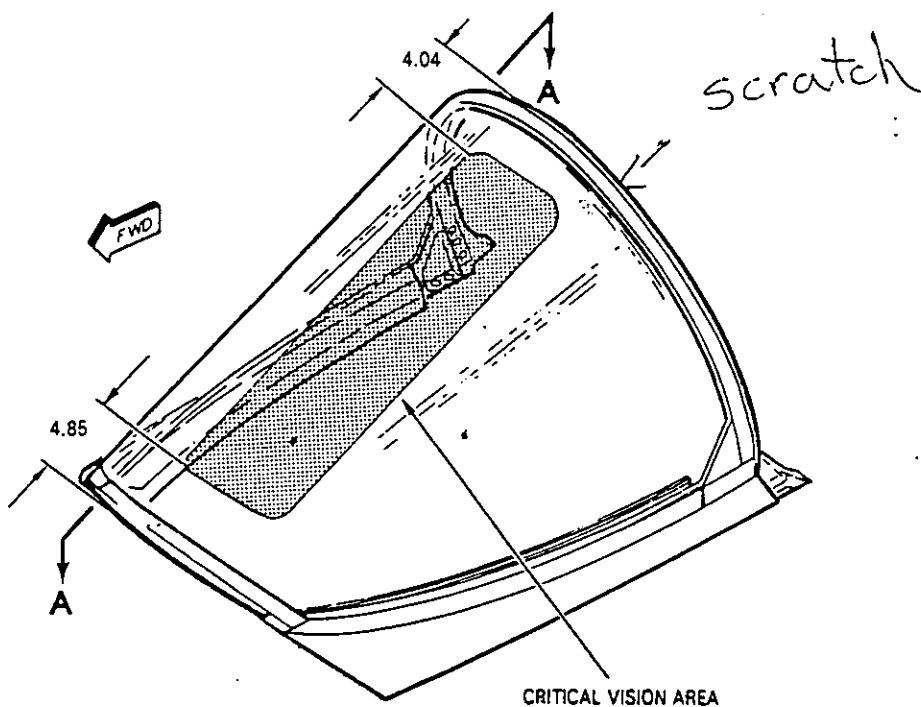
2. Optics are acceptable per item e.

e. Optics defects. Assuming the pilots normal flight position in the cockpit and/or rear cockpit, if applicable, and viewing through the transparency against the sky and terrain, any defect that does not cause the viewer to focus on the defect, thereby causing distraction, is acceptable.

EXAMPLE: A defect in the left or right vision area may be unacceptable; the same type defect elsewhere could be acceptable.

f. Phenolic fiberglass strip damage. Delamination of fiberglass strips may occur as a result of wind, rain or hail erosion. The strips are added to provide a countersink surface for the flush attach bolts. Delamination may occur to the extent of removal of the strip down to the last lamination between fasteners with enough remaining under the countersink to make sure a tight fit exists for the bolts. Delaminated and missing phenolic fiberglass strips may be repaired per paragraph 4-74B or 4-74F.

A/C 9025



15C-3-4-(4.133)

Figure 4-6B. Acrylic Transparency Rework Diagram, 68A350016

Change 38

4-27

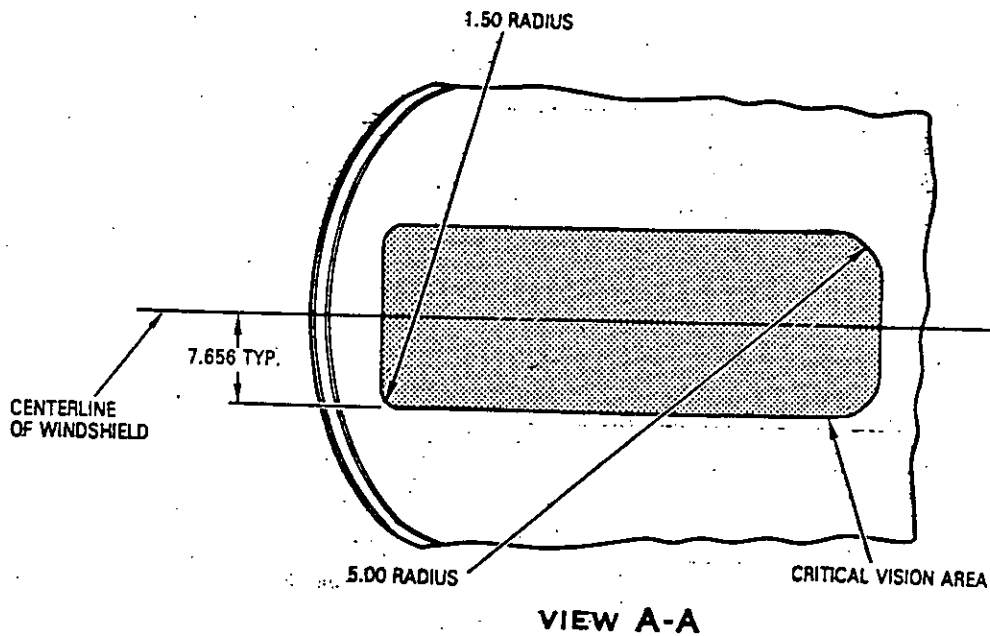
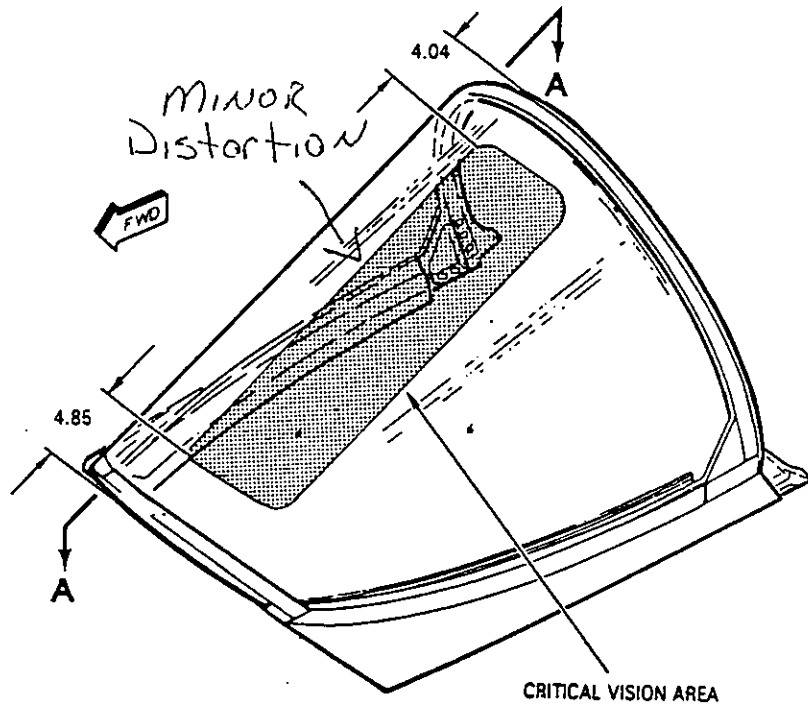


Figure 4-6B. Acrylic Transparency Rework Diagram, 68A350016

TAB O-5

F-15C 84-0025

O-5a

O-5a Maintenance Technical Report

O-5b IFF/AAI Technical Report

O-5b

TECHNICAL REPORT

F-15 Air-to-Air Identification-Friend-or-Foe (IFF) Interrogation (AAI) System

Aircraft Evaluated: F-15C, Tail Number 84-0025

Incident Date: 14 April 1994

I. INTRODUCTION: The purpose of this evaluation was to determine the serviceability of F-15C 84-0025's AAI system.

II. BACKGROUND: The accident involved the crash of two US Army Black Hawk helicopters, serial numbers 88-26060 and 87-26000, and the possible involvement of US F-15 fighter aircraft, serial numbers 79-0025 and 84-0025, and a US AWACS, aircraft serial number 77-0351, in the crash of these helicopters in the northern No-Fly-Zone of Iraq on 14 April 1994.

Aircraft 84-0025 arrived at Incirlik AB on 6 April 1994 and had flown 9 sorties since its arrival, prior to the mishap sortie.

III. EVALUATION: A review of the historical maintenance records for F-15C 84-0025 was completed. This review included the current AFTO Form 781 aircraft maintenance records, aircraft historical records, and computerized equipment history. The purpose of the review was to identify any history of pilot reported discrepancies documented on the aircraft's AAI system.

Pilot testimony to the board was also reviewed to determine their assessment of the aircraft's AAI system performance on the sortie prior to the mishap, the mishap sortie, and the sortie after the mishap sortie.

An F-15C maintenance technical advisor performed a ground operational check of the aircraft's AAI system in accordance with Technical Order (T.O.) 1F-15C-2-34JG. (Atch 2)

After the completion of the ground check, the following components were removed from the aircraft and sent to Air Force tear down test facilities for detailed analysis:

Component	National Stock Number	Teardown Facility
AAI Interrogator Computer (KIR 1C)	5810-01-273-7819	AF Cryptologic Support Center Kelly AFB, TX
AAI Receiver Transmitter R/T	5985-01-272-8047	Warner Robins Air Logistics Center Robins AFB, GA
IFF Reply Evaluator (IRE)	5985-01-016-2209	Warner Robins Air Logistics Center Robins AFB, GA

high confidence target. A low confidence target is one that has correctly replied to a Mode I, II or III interrogation. A high confidence target is one that has correctly replied to a Mode IV interrogation.

The F-15C has an interference blanking system (IBS) whose purpose is to prevent interference between active aircraft systems on the same aircraft which could be brought about by multiple radio frequency transmitters and receivers. The only component of the IBS is the interference blanker. When a system on the F-15 is sending a signal through its receiver/transmitter, the interference blanker sends an electrical signal to other systems preventing them from inadvertently receiving that signal through their receiver/transmitters.

B. HISTORICAL RECORDS REVIEW. A review of the historical maintenance records for aircraft 84-0025 showed the aircraft experienced no AAI failures between 1 December 1993 and 9 March 1994. The pilot reported an AAI malfunction in flight on 9 March 1994. The AAI system Built-In-Test (BIT) failed, although the system operation appeared to be normal. Maintenance was unable to duplicate the problem and returned the aircraft to service. **(Tab H5i)**

The aircraft was modified by TCTO 1229 on 16 March 1994, incorporating the new electronically keyed KIT 1C/TSEC and KIR 1C/TSEC into the IFF and AAI system. **(Tab U5b)** These new components improve the reliability of loading Mode IV codes into the aircraft's AAI and IFF systems.

A pilot reported the aircraft had an in-flight problem on 23 March 1994 with the AAI system unable to interrogate any modes. Maintenance replaced the AAI R/T and the AAI was confirmed as serviceable. **(Tab H5h)** That pilot also reported the aircraft's IBS BIT light was illuminated on the same flight, indicating a problem with the aircraft's interference blanking system. Maintenance replaced the aircraft's interference blanker and the aircraft passed the serviceability check. **(Tab H5h)**

On 8 April 1994, a pilot wrote up the AAI system for a discrepancy indicating another possible problem with the interference blanking system. Maintenance was unable to duplicate the malfunction and returned the aircraft to service. **(Tab H5f)**

On 13 April 1994, on the sortie prior to the mishap sortie, the pilot reported an IBS BIT light, indicating the interference blanking system had failed an internal self-test. Maintenance replaced the interference blanker and the system was confirmed serviceable by maintenance. **(Tab H5g)**

C. PILOT ASSESSMENT. The pilot who flew aircraft 84-0025 on 13 April 1994 (the sortie prior to the mishap sortie) used the aircraft's AAI system to successfully interrogate the other F-15C in his flight with both Mode I and IV. **(Tab V30/Q20;Q22)** The pilot of 84-0025 on the mishap sortie also used the aircraft's AAI system to successfully interrogate the other F-15C in his flight with both Mode I and IV. **(Tab V29/Q32)** The pilot of 84-0025 on the second sortie on 14 April 1994 (the sortie after the mishap sortie) used the aircraft's AAI system to successfully interrogate the other F-15C in his flight with both Mode I and IV. **(Tab V31/Q16)** The pilot did

Interference Blanker 5865-01-114-2469

Warner Robins Air Logistics Center
Robins AFB, GA

AAI Cockpit Control Panel 5985-01-044-4987

Warner Robins Air Logistics Center
Robins AFB, GA

Specific maintenance procedures with possible relevance to the mishap were investigated. The 53rd Fighter Squadron's policies and procedures for loading Mode IV codes into the aircraft and for operationally checking the validity of those codes were reviewed and the squadron's adherence to those policies and procedures was evaluated.

IV. DETERMINATION:

A. BACKGROUND. (The following information is derived from T.O. 1F-15C-2-34GS-00-1, dated 1 Apr 81, change 26, dated 15 Jul 93 and T.O. 1F-15C-2-99GS-00-1, dated 1 May 91, change 4, dated 15 Aug 93)

The F-15C AAI system is an airborne IFF interrogator operating on Modes I, II, and III, plus a security mode (Mode IV). The system interrogator receives IFF replies from other aircraft, decodes them, then displays the appropriate symbology on the Vertical Situation Display (VSD) screen in the cockpit. The AAI system is comprised of an AAI control panel, a throttle multifunction switch, an IFF reply evaluator (IRE), an interrogator computer (KIR 1C/TSEC), 10 dipole antennas and an AAI receiver/transmitter (R/T).

The pilot initiates the interrogation process by moving the throttle multifunction switch to the left. This action sends the interrogate command to the radar system where it is processed and then sent on to the IRE for processing for use in the AAI system. At this time, the pilot will see an "I" displayed in the lower left corner of the VSD indicating that the interrogation process is in progress. The IRE produces an interrogation signal based on the requested mode (I, II, III, or IV) selected from the cockpit AAI control panel and sends this signal to the R/T unit. Additionally, if Mode IV is the mode selected by the pilot, an interrogate command is routed from the IRE to the KIR 1C/TSEC interrogator computer which sends the current day's coded data back to the IRE to be included in the transmitted signal. The R/T unit transmits the interrogation signal through the AAI antennas that are mounted on the radar antenna.

The interrogation signal is received by an IFF transponder system in another aircraft which automatically sends back a coded return signal. This return signal is received through the AAI antennas mounted on the radar antenna, and is processed in the receiver portion of the R/T. The coded data is stripped from the received signal by the R/T, then sent to the IRE where the coded data is processed to determine its validity. For Mode IV interrogations, the reply portion of the return signal is routed to the KIR 1C/TSEC interrogator computer which interprets the reply for validity. A valid reply will trigger a Mode IV OK response to be sent back to the IRE. When a valid return signal is received, a signal is sent by the IRE to the radar telling it to display an AAI target return on the VSD. This signal is displayed on the VSD as either a circle or a diamond. The diamond symbology indicates a low confidence target and the circle symbology indicates a

note an interference blanking system anomaly but did not write up the system as he did not see any performance degradation (Tab V31/Q20)

D. FUNCTIONAL CHECK. A functional check of the aircraft's AAI system was conducted by an F-15 maintenance technical advisor on 20 and 21 April 1994. This test was performed using the AN/APM-349 Interrogation Systems Test Set. The test indicated the aircraft was capable of interrogating and displaying Mode I, II, and III low-confidence targets and Mode IV high confidence targets generated by the test set. The aircraft failed the Mode IV loop check, a internal self-test of the Mode IV system. This test sends a Mode IV interrogation through the AAI transmitter and then evaluates whether the signal is received by the IFF system's receiver. The technical advisor was unable to confirm his suspicion that the interference blanker system discrepancies and the failed Mode IV loop check were related (Attach 2)

Based on the previously identified IBS problems with this aircraft, the technical advisor functionally checked the continuity of the aircraft wiring that carries the blanking signal between the interference blanker, the IFF system, and the AAI system. All wires checked good, in accordance with T.O. 1F-15C-2-00WD-10-1. (Atch 2)

E. TEARDOWN ANALYSIS. The aircraft's IRE, AAI R/T, KIR 1C/TSEC, interference blanker, and AAI cockpit control panel were removed from the aircraft and sent to Air Force testing laboratories for tear down analysis. The IFF R/T, interference blanker, AAI cockpit control panel, and IRE were sent to Warner Robins Air Logistics Center (WR ALC) and the KIR 1C/TSEC was sent to the Air Force Cryptologic Support Center, Kelly Air Force Base, Texas.

The analysis of the IRE (serial number 1444) at WR ALC showed that, prior to the teardown, the unit met all functional test requirements. During teardown and individual circuit card testing, one circuit card had an out-of-tolerance test condition. Engineering analysis determined the discrepancy would have had no effect on the performance of the IRE. (Tab J5c)

The analysis of the AAI R/T (serial number OKJ00199) at WR ALC indicated the unit was in good operating condition and met all critical test requirements. (Tab J5b)

The analysis of the KIR 1C/TSEC (serial number 00936) at the Air Force Cryptologic Support Center at Kelly Air Force Base indicated the KIR 1C/TSEC passed all tests. (Tab J5a w/o attach)

The analysis of aircraft 84-0025's interference blanker (serial number 0206) at WR ALC indicated the unit met all functional test requirements. (Tab J5e) A second interference blanker (removed from 84-0025 on 13 April 1994 to correct an IBS problem) (serial number 0687) was also sent to WR ALC for a teardown analysis. That unit met all functional test requirements as well. (Tab J5e)

The analysis of the AAI cockpit control panel (serial number 0642) at WR ALC indicated the unit passed all functional test requirements. (Tab J5d)

F. PROCEDURES:

KEYING MODE IV INTO AAI AND IFF SYSTEM PRIOR TO FLIGHT

The 53 Fighter Squadron (FS) maintenance organization enters the new day's Mode IV code into each of their aircraft's AAI and IFF system on the morning of the mission. (Tab V90/p2 para 4) This classified code is loaded into an electronic keyer (KYK-13). The electronic keyer is then used to key the IFF and AAI Mode IV systems on the aircraft. (Tab V90/p2 para 5) The Mode IV keying action is documented by a write-up in the aircraft forms binder.

The board received an inquiry from an individual employed by a company who printed the technical data changes for the upgrade of the F-15 KIT 1A to the KIT 1C. The employee was concerned that the new technical data was not detailed enough for the procedure to load the Mode IV codes into the new KIT 1C. (Tab V39/p2para3) An investigation showed the employee to be correct and the F-15 technical advisor has submitted a change to technical data (AFTO Form 22) to significantly expand the existing technical data. Although the technical data does not contain detailed information on loading Mode IV codes, it was determined that this technical data deficiency did not prevent the maintenance technicians from correctly loading the codes.


Aircraft 84-0025's IFF and AAI systems were keyed on the morning of 14 April 1994. (Tab V90/p3 para 2) This action was properly documented in the aircraft forms binder. (Tab H5-b) The technician's training records indicate he was qualified to perform that task. (Tab T6-a)

CHECKOUT OF MODE IV PRIOR TO FLIGHT

The 53 FS maintenance policy, while deployed to Turkey, is to perform an operational check of each aircraft's IFF system just prior to takeoff on every Operation PROVIDE COMFORT mission. (Tab V38/p1 para 5) An avionics technician, using an AN/APM-424 Transponder Test Set, interrogates each aircraft as it sits at its end-of-runway check. (Tab V40/p2 para 1) If the aircraft properly replies to the interrogation, the avionics technician receives a green light in the tester, and the pilot receives an audible tone, a light, or both in the cockpit. (Tab V40/p2 para 4) This check confirms the correct Mode IV code was entered into the aircraft's IFF transponder computer (KIT 1C/TSEC). Since the Mode IV code is loaded simultaneously into the KIT 1C/TSEC and the AAI interrogator computer (KIR 1C/TSEC) (Tab V90/p2 para 4), this check also confirms the correct Mode IV code was loaded into the AAI system. It is squadron policy to ground abort an aircraft that does not pass this operational check of the IFF system. (Tab V38/p2 para 2)

A squadron avionics technician interrogated 84-0025 using the IFF test set on the morning of 14 April 1994 as it prepared for takeoff on the mishap sortie. The technician received a green light in the IFF test set and the pilot gave a "thumbs up" indicating he had received the proper cockpit indication. (Tab V40/p2 para 4) The pilot later stated that he had received a correct cockpit

indication. **(Tab V29/Q32)** The technician's training records indicate he was in training for the operation of the IFF test set (i.e., training start date documented but training complete date not entered) . **(Tab T6b)** An F-15 maintenance technical advisor evaluated this technician on the operation of the IFF test set, on 28 April 1994, and found him to be proficient in its use. **(Atch 3)**


JEFFREY M. SNYDER, Maj, USAF
F-15 Maintenance Board Member

3 Atchs

1. Statement of Certification
2. F-15 Technical Advisor's report
w/o attachments
3. F-15 Technical Advisor's memo

STATEMENT OF CERTIFICATION

I am Major Jeff Snyder, assigned to the 48th Fighter Wing, RAF Lakenheath England as the squadron maintenance officer, 493rd Fighter Squadron. I am the F-15 maintenance board member on the AFR 110-14 Accident Board, investigating the crash of two US Army Black Hawk helicopters and the possible involvement of US fighter aircraft in the crash of these helicopters in the northern No-Fly Zone of Iraq on 14 Apr 94. I have held various positions as a F106 and F-15 maintenance officer, squadron commander, and logistics staff officer over the past 15 years. I have been a maintenance training squadron commander and equipment maintenance squadron commander. I served as Research Fellow at RAND Corporation and as Chief, Maintenance Plans and Policy Branch at HQ United States Air Forces in Europe. I received my Master's Degree in Logistics Management from the Air Force Institute of Technology. I have been associated with the F-15 since 1983.

Date: 5/16/94


JEFFREY M. SNYDER, Major, USAF
F-15 Maintenance Board Member

REPORT
ON
AIR-TO-AIR IFF INTERROGATOR (AAI)
SYSTEM
OPERATIONAL CHECKOUT
F-15C 84-0025
CONDUCTED 20/21 APRIL 1994
BY
GERALD D SILVIUS, GS-11
F-15 MAINTENANCE TECHNICAL ADVISOR

CERTIFICATE

I certify that I am the Records Custodian for the Accident Investigation Board convened to investigate the crash of two U.S. Army Black Hawk helicopters in the no fly zone in northern Iraq on 14 April 1994, and that this is a true and accurate copy of the record which is kept in my records system.

2 May 94
Date

William L. Harris
WILLIAM L. HARRIS, Capt, USAF, MSC
Evidence Custodian, Incirlik Air Base, Turkey

Attachment with...

PREFACE

This is a brief explanation of terms that will be used in the following description of the maintenance testing of F-15C aircraft tail numbers 840025 and 790025.

VSD Vertical Situation Display

BIT Built in Test

IFF Identification Friend-or-Foe transponder system. The IFF transponder system does the self-identification function for the aircraft. The system receives challenging signals (interrogations), determines authenticity and mode of challenge, and automatically transmits coded replies. The system operates in Modes I, II, and III/A, which are Selective Identification Feature (SIF) modes, plus security Mode IV.

AAI Air-to-Air IFF Interrogator system. The AAI system is an airborne IFF interrogator, independent of the IFF transponder, operating on the standard SIF feature Modes I, II, and III, plus Mode IV. The system transmits challenge signals and receives replies through antennas mounted on the radar antenna. The system decodes IFF replies to develop a confidence level display correlated with radar targets of the radar VSD.

AAI A built in test used to determine the serviceability of the AAI interrogator system,
BIT exclusive of the Mode IV BIT test. Can be initiated by maintenance personnel or aircrew.

Loop Mode IV initiated BIT. An initiated BIT check that enables the maintenance
Check technician to check the Mode IV serviceability of the IFF and the AAI systems. The BIT circuitry enables the on board AAI system to interrogate the on board IFF system, giving go/nogo indications to the technician.

424 Transponder Set Test Set, AN/APM-424. A small, hand held test set that provides a
Tester complete checkout of all IFF transponder features, including Mode IV. The test set interrogates the aircraft IFF system, receives the coded replies, determines the authenticity of the replies and displays the result as a go/nogo display to the operator.

349 Interrogator Systems Test Set, AN/APM-349. A flightline test set that provides a
Tester checkout of all aircraft AAI system modes, including Mode IV. The test set acts as an
IFF transponder that automatically transmits replies to aircraft interrogations in SIF
modes I, II, III, and Mode IV. During the interrogation test, the tester displays an
accept light for proper aircraft interrogations and the aircraft will display an applicable
low or high confidence target on the VSD. SIF mode targets will be displayed as low
confidence targets and Mode IV targets as high confidence targets.

AIRCRAFT 840025
20 APRIL 1994

Opened up the aircraft panels and visually inspected the AAI/IFF systems for serviceability. The components all appeared to be in good condition. A visual inspection of cockpit revealed the following control switch positions: AAI Mode select switch was set to 4A, the code wheels were set to 4300. The IFF Mode IV switch was set to "A", the IFF Mode I code was 43, the IFF Mode III/A code wheels were set to 2410, IFF Mode I switch was set to ON, the IFF Mode II switch was set to OUT, and the IFF Mode III/A switch was set to OUT.

The units installed in the aircraft were as follows; AAI Receiver/Transmitter (R/T), Radio, RT868D/APX-76(V), serial number OKJ 00199. AAI Radar Target Data Processor, MX9147A/APX, serial number 1444. KIR-1C/TSEC Interrogator Computer serial number 00936.

Performed the safe for maintenance checks, power on checks, attached ground equipment to the aircraft, and applied power to the aircraft. Applied power to the 349 tester, serial number DGX-128, and ran the self checks which failed. Obtained a second tester, serial number DGX-86, and found that it was 16 days past due calibration. The decision was made to proceed with the aircraft checkouts with the out of calibration tester to get an indication of the AAI system serviceability.

The first check to be accomplished was the AAI BIT check IAW T.O. 1F-15C-2-34JG-53-1 (Atch. 1). After system warm up, the BIT check passed 6 out of 6 attempts.

The next check to be accomplished was the Mode IV Loop Check IAW T.O. 1F-15C-2-34JG-53-1 (Atch. 1). This test failed every time attempted. It was run intermittently over the course of the entire checkout procedure and failed a total of 9 times. The aircraft's IFF system would not give an indication that it was being interrogated by the aircraft's AAI system.

The next check accomplished was the AAI operational checkout using the 349 tester IAW T.O. 1F-15C-2-34JG-53-1 (Atch. 1). The steps listed are the actual operational testing after the set-up procedure:

checks, attached ground equipment to the aircraft, and applied power. Applied power to the 349 tester and ran the self checks which passed.

The first check to be accomplished was the AAI BIT check IAW T.O. 1F-15C-2-34JG-53-1 (Atch. 1). After system warm up, the BIT check passed 6 out of 6 attempts.

The next check to be accomplished was the Mode IV Loop Check IAW T.O. 1F-15C-2-34JG-53-1 (Atch. 1). This test again failed every time attempted. It was run a total of 6 times and all 6 failed. The IFF system would not give any indication that it was being interrogated by the AAI system.

The next check accomplished was the AAI operational checkout using the 349 tester IAW T.O. 1F-15C-2-34JG-53-1 (Atch. 1). The steps listed are the actual operational testing after the set-up procedure;

STEP	MODE	RESULTS
29-31	M-III	The aircraft successfully interrogated the 349 tester displaying the interrogation cue and a low confidence target at the proper range on the VSD. The 349 accept light illuminated indicating that the interrogations were correct. Interrogated the tester 6 times with the same result.
32	M-III	A second Mode III test with a different code set into the control head. The aircraft display was correct and the accept light illuminated on the 349 tester. Interrogated 6 times successfully.
33-40	M-II	The aircraft displayed the interrogate cue on the VSD and a low confidence target at the proper range. The 349 tester accept light was illuminated. Interrogated 6 times successfully.
41-44	M-I	The aircraft displayed the interrogate cue on the VSD and a low confidence target at the proper range. The 349 tester accept light was illuminated. Interrogated 6 times successfully.

STEP	MODE	RESULTS
29-31	M-III	The aircraft successfully interrogated the 349 tester displaying the interrogation cue and a low confidence target at the proper range on the VSD. The 349 reject light was on continuously even though the aircraft system appeared to operate correctly. A second 349 tester self check was performed successfully indicating that the tester was capable of displaying the accept light. Interrogated the tester 6 times with the same result.
32	M-III	A second Mode III test with a different code set into the control head. The aircraft display was correct but the reject light was illuminated on the 349 tester. Interrogated 6 times.
33-40	M-II	The aircraft displayed the interrogate cue on the VSD but no low confidence target was displayed and the 349 tester reject light was illuminated. Interrogated 6 times.
41-44	M-I	The aircraft displayed the interrogate cue on the VSD but no low confidence target was displayed and the 349 tester reject light was illuminated. Interrogated 6 times.
45-57	M-IV	The aircraft displayed the interrogate cue and a high confidence target at the proper range on the VSD for Mode IV A and B codes. Had a hard reject light on the 349 tester continuously. Interrogated Mode IV A and B codes 6 times each.

**AIRCRAFT 840025
21 APRIL 1994**

After obtaining another 349 tester, serial number DGX-59, which was in calibration, the entire testing procedure was performed again. Performed the safe for maintenance checks, power on


45-57 M-IV The aircraft displayed the interrogate cue and a high confidence target at the proper range on the VSD for Mode IV A and B codes. The accept light on the 349 tester illuminated properly. Interrogated Mode IV A and B codes 6 times each successfully.

The successful completion of all the preceding checks indicate that the AAI system was operational. To further prove the AAI/IFF system reliability a 424 tester was used to interrogate the IFF system separately to determine if there was a problem with the IFF system. The 424 tests passed four times in succession indicating that the IFF system was operational.

In light of the previously reported Interference Blanking System (IBS) problems, I checked the wiring that carries the blanking signals between the Interference Blanking (IB), the IFF system and the AAI system. I checked the wiring for open circuits, short circuits to ground, high resistance open circuits and high resistance circuits to ground utilizing a Hewlett Packard model 8205 multi-meter and a Tektronix model 1502 Time Domain Reflectometer (TDR). The following wires were tested for continuity utilizing T.O. 1F-15C-2-00WD-10-1 as reference (Atch. 2); connectors 103P-B001B pin 38 to 67P-B001C pin 13, 103P-B001B pin 39 to 67P-B001C pin 14, 102P-B001A pin 6 to 67P-B001A pin J, 79P-B001B pin E to 67P-B001B pin J, and 79P-B001B pin A to 67P-B001A pin K. All the wires tested checked good while moving and stressing the wire bundles as much as possible in an attempt to duplicate any possible malfunction that would arise from "G" loading and inflight vibrations.

CONCLUSION

At the time of the operational checks, despite the Mode IV Loop Check failure, the AAI system installed in aircraft 840025 was capable of interrogating and displaying Modes I, II, and III low confidence targets, and Mode IV high confidence targets.


Gerald D. Silvius, GS-11, DAF
F-15 Technical Advisor

2 Attachments:

~~1. Excerpts from TO 1F-15C-2-34JG-53-1~~

~~2. Excerpts from TO 1F-15C-2-00WD-10-1~~

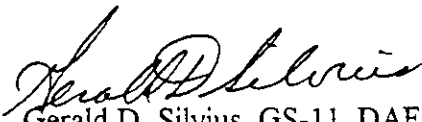
W. H. ...

Memorandum for Record

30 April 1994

TO: Whom it May Concern

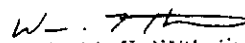
At Major Snyder's request, on the morning of 28 April, I observed Airman Norman interrogate the Identification Friend-or-Foe systems on two 53 FS F-15C aircraft with the AN/MPM-424 test set. The interrogation was being performed on the aircraft as they were stopped on the taxi way adjacent to the 53 FS parking area as required by 53 FS policy for mode 4 checks prior to flight at OPC. He performed step 4 of the test set self test procedure and step 40 of the mode 4 test as shown in TO 1F-15C-2-34JG-52-1 correctly on both aircraft. Successful completion of these steps satisfies the requirement for the prior to flight mode 4 check.


Gerald D. Silvius, GS-11, DAF
F-15 Technical Advisor

CERTIFICATE

This Memorandum for the Office of Investigation and Control
is a true and correct copy of the original document as shown
to me on 15 May 1994, and it is true and correct copy
of the original document as shown to me on 15 May 1994.

15 May 94


WILLIAM L. HARKIN, USAF USAF MSO
Fielding Operations
Inflight Air Force, Sydney

TAB O

ADDITIONAL SUBSTANTIATING DATA REPORTS

	O-1
	O-2
O-1 UH-60 Black Hawk 88-26060	O-3
O-2 UH-60 Black Hawk 87-26000	O-4
O-3 E-3B AWACS	O-5
O-4 F-15C 79-0025	O-6
O-5 F-15C 84-0025	
O-6 Human Factors	
O-7 Medical Reports	
O-8 Optics Report	
O-9 Crash Site Analysis Technical Report	
O-10 Technical Report, F-15C IFF/AAI Systems (See also Classified Addendum)	
O-11 Technical Report UH-60 Black Hawk IFF/AAI Systems	

TECHNICAL REPORT HUMAN FACTORS

I. INTRODUCTION

The purpose of this evaluation was to discover the perceptions of the crew members aboard USAF AWACS aircraft serial number 77-0351 and assess their impact on crew performance on 14 April 1994, and to discover the perceptions of the F-15C flight lead of the incident aircraft and assess their impact on the mis-identification of two US Army Black Hawk helicopters, serial numbers 88-26060 and 87-26000.

This report was prepared for the official AFR 110-14 aircraft accident investigation into the facts and circumstances surrounding the crash of two US Army Black Hawk helicopters and the possible involvement of US fighter aircraft and a US E-3B AWACS aircraft in the crash of these helicopters.

II. BACKGROUND

This technical advisor is presently the Chief Air Force Aviation Psychologist, Headquarters Air Force Safety Agency. I have held this position since 1988. I graduated with highest honors with a Bachelor of Science from Dakota State College in 1961 and received my Doctoral Degree in Psychology (Ed D) in 1974 from Ball State University, Muncie, Indiana.

I joined the Air Force in 1979 and was assigned to the USAF hospital, Ellsworth AFB, South Dakota as the Clinical Psychologist. In 1982, I completed Squadron Officers School in residence and was assigned to Grissom AFB, Indiana as Chief of the Mental Health Clinic.

I was subsequently assigned as Chief Psychologist, USAF Hospital and attached to the Fighter Squadron, Bitburg AB, Germany in 1984 where I developed a Human Factors training program for the F-15 and F-4 Flight Commanders at Bitburg and Spangdahlem Air Bases. In 1985, I graduated as an aviation psychologist from the USAF School of Aerospace, Brooks AFB, Texas.

In May 1988, I was assigned to the Air Force Inspection and Safety Center (AFISC) at Norton AFB, California as the Chief Air Force Aviation Psychologist. I developed training programs for various Air Force Major Commands, with special emphasis on psychosocial stressors.

The focus of this report is to determine the effect of human factors (the study of capacities and limitations of the human side of safety, AFP 127-1, Vol. III) on the F-15 pilots and AWACS crewmembers involved in the 14 April 1994 accident.

III. EVALUATION

The assessment and evaluation was based upon life science interviews with AWACS crew members conducted with Maj Chris Lisanti, Flight Surgeon member of the AFR 110-14 board. These interviews collected data about crewmembers' activities 2 weeks and 72 hours prior to the accident, information on their perceptions of the ROE and responsibilities of the AWACS at OPC.

Further, assessment and evaluation was based upon my personal observations during witness testimony to AFR 110-14 board members, my review of AWACS training and medical records, and my review of transcripts of witness testimony taken by the investigation board.

IV. DETERMINATIONS

A. AWACS

This advisor determines three perceptions were evident among the AWACS crew members.

1. AWACS CREW MEMBERS FELT THEY WERE NOT RESPONSIBLE FOR TRACKING HELICOPTERS

This perception was repeated throughout the testimony of AWACS crew members. As one surveillance technician testified, "We rarely deal with helicopters.." (V21/Q63). In my previous rotation here, my previous TDY I don't remember maintaining a picture on any helicopters in the AOR. I found these helicopters in the AOR to be an unusual event (V21/Q66-67). "As I understand it, sir, we know the helicopters are going to be there if they decide to tell us. But we don't talk to them, we don't see them, unless they decide to do that to us. So as I understand it, we are kind of left out of the loop with them. We're not always sure of what they're doing" (V21/Q90).

Another surveillance technician related, "We did not have a flight plan on Eagle Flight aboard the airplane. From what I understand, we do not normally get flight plans on helicopters. We do not receive any briefings on the route of flight for the helicopters" (V22/p3para7). The air surveillance officer on board the AWACS on 14 April 1994 supported this perception by testifying, "Since I've been here, we have never tracked helicopters in surveillance. The weapons team talks to them so they are responsible for tracking" (V18/Q29). When asked whether surveillance received any flight plans on the helicopter prior to taking off, the surveillance officer replied, "No sir, we don't have a takeoff time, no flight plan" (V18/Q134). "It's not our [surveillance team's] responsibility [to track Eagle flights]" (V18/Q139/Q140-143).

However, when the staff mission crew commander testified regarding the weapons crew members responsibility in OPC, he said, "The primary mission of the weapons section...is to control fighters" (V13/Q85-88). He further testified that no one is specifically assigned the responsibility for monitoring friendly helicopter traffic in the no-fly zone (V13/Q91) and he admitted "There are no procedures" if there is a loss of radar contact with helicopters (V13/Q216-219). He also reported if a helicopter disappears and you knew he was enroute from a particular point to another, there are no written procedures telling them whether to zero the track out or not (V13/Q254). He goes on to explain that AWACS receives helicopter flight plans only when the helicopter "checks in." He relates, "Occasionally they will check in and tell us everything they're doing all day long. Sometimes, they'll check in and we'll never hear from them again" (V13/Q324). The staff mission crew commander further reported, he never received flight information on helicopters from other agencies. Receiving information from helicopters depended upon the particular pilot (V13/Q328-330).

The senior weapons director supported the view of no responsibility towards helicopters in OPC. He testified, "there's not any real routine" for helicopters landing and taking off in the no-fly zone. "...the majority of them land and take off without telling us" (V14/Q188). The AWACS enroute controller stated, "...they [helicopters] fly whatever route they want to. If they report in at all, they'll say we are going from this point to this point, but we don't have a route or they don't tell us [where they're going]" (V16/Q143).

The extent to which the AWACS crew members perceived no responsibility for tracking helicopters is summarized in the testimony of the senior weapons director. When asked about the possibility the identified Iraqi Hind helicopters could have been Eagle Flight, the day of the incident he replied, "The Black Hawks weren't even a thought" (V14/Q343).

2. AWACS CREW MEMBERS SEEMED CONFUSED AND UNCERTAIN ABOUT THEIR ROLES REGARDING TRACKING IN THE AOR

Testimony by crew members also supported this perception. One surveillance technician related, "A friendly helicopter that is on a mission and communicating with us would probably [emphasis added] be...tracked by our weapons people..." (V21/Q26). He further stated, "I don't remember them specifically addressing" whose responsibility it was for tracking targets north of the 36 parallel in Iraq. "I assume [emphasis added] that would be a surveillance mission..." (V21/Q59). When questioned as to who was responsible for placing symbology on the helicopters, he stated the symbology [on Eagle Flight] would have been placed on the track by someone in the AWACS crew. He further stated that he didn't know who would normally have this responsibility within weapons (V21/Q77).

Another air surveillance technician stated, "We go over what we're suppose to be tracking. The discussion at home base is not that specific as to what kind of tracking, type of aircraft, who is going to be tracking what aircraft, or what the AOR looks like" (V22/p1para5). "It wasn't that specific when we got here either because we had to call weapons to know what we were supposed to be tracking" (V22/p2para1). He goes on to state, "I was briefed to expect F-15s. I did not know about Eagle Flight" (V22/p2para3).

The air surveillance officer stated, "The AWACS crew consider the Eagle Flight to be OPC aircraft... that automatically switches to weapons section for responsibility for tracking." (V18/Q113-114). However, the staff mission crew commander offered a slightly different perception when he said, "The surveillance area of responsibility is maximum 360 degrees coverage... with the additional tasking of the no-fly zone" (V13/Q79). He related, in the OPC AOR, the surveillance section has primary responsibility for locating, identifying, and monitoring aircraft (V13/Q81-82). He also reported, the weapons section has "...very limited responsibility..." for tracking helicopters in the no-fly zone (V13/Q90). However, the senior weapons director said something different. He related, "Once a helicopter is tagged with symbology in the AOR, the AOR controller is responsible for tracking." But he also said, "Most of the time, they [helicopters] would check up with us on the check in frequency. So, the person that would be talking to them would be the enroute controller" (V14/Q74-75). He testified, "The enroute controller would have probably [emphasis added] handed them [Eagle Flight] off to the AOR controller...My understanding [emphasis added] is the helicopters are supposed to be monitoring the AOR clear frequency. ...then they would have been able to talk to the AOR controller, which

they should when they're in the AOR" (V14/Q124). The air surveillance officer offered another perspective by stating, "Since I've been here, we have never tracked helicopters in surveillance. The weapons team talks to them so they are responsible for tracking" (V18/Q29).

However, another AWACS controller stated, "We never had any guidance at all on helicopters." (V16A/Q12). " I suppose (emphasis added) if somebody were to be assigned the responsibility, it would have been the responsibility of the AOR controller" (V16/Q22).

3. AWACS CREW MEMBERS FELT THEY LACKED CONTROL AUTHORITY OVER FIGHTER AIRCRAFT IN OPC

Testimony from AWACS crew members supported this contention. The staff mission crew commander related that if the MCC wanted to make a change of missions on the ATO, "He'll be overridden by the Duke. The Duke is responsible for the flight flow. If we don't say, 'Duke directs,' then the fighters normally will not obey the command. Fighters should comply with AWACS controllers requests to terminate engagements. Whether they will or not is your guess as well as mine" (V13/Q137). When the tanker controller was questioned whether anyone on board had commit authority for fighters, he responded, "He [sic] does not have commit authority. That's up to the tactical planes" (V17/Q47). The senior weapons director also stated, "Its not my position to stop an intercept with the fighters already engaged" (V14/Q70). When queried as to whether the controllers should relay an order to the intercepting pilot to fire warning shots, he responded with, "No" (V14/Q107).

B. F-15C FLIGHT LEAD

This advisor determines the following factors contributed to the visual mis-identification by the F-15C flight lead of Iraqi Hind helicopters.

1. FLIGHT LEAD BELIEVED NO AIRCRAFT WERE TO BE IN THE AOR AHEAD OF FIGHTERS AND NO FRIENDLY HELICOPTER ACTIVITY WAS IDENTIFIED FOR THAT DAY IN THE AOR

Testimony verified these contentions. The flight lead stated, "The ACO...says that aircraft with AI radars, will be the first people to enter the AOR each day to sanitize. So my understanding is, if you're the first F-15 flight of the day...you will be the first in the area. No one else will be allowed in until you ensure that there are no Iraqis in the area" (V29/Q84). The F-15C wingman also supported this by stating, "...ACO guidance that [states] no aircraft will enter the AOR until fighters... sanitize it..." (V28/Q13). The AWACS tanker controller also related, "Tiger flight is supposed to be the first aircraft into the AOR" (V17/Q214) and the air surveillance officer stated, "The F-15s are the first ones. They are the primary air-to-air players out there. They go out into the area of responsibility before anybody else..." (V18/Q150).

Not only did the F-15C flight lead and wingman believe they were to be the first aircraft in the AOR, they also had not heard any information about any friendly helicopter activity in the AOR the day of the incident. The F-15C wingman related, "On the morning of 14 April, I met the flight leader... and we drove to the squadron operations building. ...we proceeded to Intel section and received a briefing from the squadron Intel officer... there was no mention of any helicopter

activity in the AOR" (V28/Q13). The F-15C flight lead supported this with, "Nothing at all was briefed about helicopters" (V29/Q24). The wingman further related, there was no information on the daily flow sheet about Eagle Flight (V28/Q17). And the F-15C flight lead stated, "We did that and also noticed there is [sic] no helicopters on the frag..." (V29/Q25).

2. MINIMAL VISUAL RECONNAISSANCE, LOW ALTITUDE INTERCEPT TRAINING MADE THE PILOTS UNCOMFORTABLE WITH THE INTERCEPT PARAMETERS

Testimony presented by the two F-15C pilots supported this perception. The F-15C flight lead explained, "Since January the 1st, due to TDYs and a move to Spangdahlem, we did not do any visual recognition training, and that's a decision between the Weapons Officer and Intel on what we need..." (V29/Q234). He goes on to explain about 5 to 10 percent of the visual recognition training related to helicopters (V29/Q234). The F-15C wingman stated simply, "...we haven't had any training like that since the first of January" (V29/Q265). He also stated that during visual reconnaissance training there were no photos of Black Hawk helicopters with auxiliary tanks installed" (V28/Q270); and the F-15C flight lead could not remember any training that pointed out Black Hawk helicopters had flags painted on them (V29/Q224).

Regarding low altitude intercept training, the F-15C wingman reported, "With twenty/twenty hind sight, given the--, everything that's unfolded... being based in Germany, we don't train below a thousand feet on a regular basis... That was a training limitation. I was uncomfortable getting down low altitude with that two ship. Primarily the reason was...I didn't have both of them in sight...the type of terrain we were looking at and trying to get down there at a helicopter flying as low as they were is not something we routinely train towards" (V29/Q257). The F-15C flight lead related, "Yes sir, RTU which is the training unit for F-15s, use to have a low altitude checkout program... that was below 5,000 feet. They did not have that when I went through due to cutbacks... So, I did no training below 5,000 feet until I got to Bitburg. I've only had two upgrade rides in low altitude training... Those were the only two times I've ever gone below a thousand feet" (V29/Q127).

3. FLIGHT LEAD RECEIVED NO INFORMATION TO DISSUADE HIM FROM HIS PERCEPTION OF IRAQI HIND HELICOPTERS

Following take off and initial entry into the AOR, the F-15C flight lead received no information to dissuade him from his perception he was to be the first aircraft into the AOR. The F-15C flight lead testified that at about 40 miles northwest of Iraq he asked the Duke if he had any information he needed to know that had changed since the briefing and he said, "negative words" (V29/Q33). "We hit Gate 1, which is the actual border between Turkey and Iraq... [I] said, 'Cougar, Tiger is on station...'. Usually, at this point, if there is any air-to-air activity anywhere in Iraq, Cougar will give us a picture call that tells us what he sees. ...He just responds, 'Roger,' with no picture calls. My assumption is that there is no air activity in the AOR at this time" (V29/Q33). The F-15C flight lead's assumption is based on the ACO which states procedure in the AOR is "min comm" which means unless something changes there will be no communication (Operation Provide Comfort ACO Vol. II p.9 Section F1). Also the flight lead reported that, "On a regular basis he (Cougar) will only talk to us with additional information. We try to use brevity. So he will not

talk to us on the radio, with the exception of telling us that he heard us... and give additional words unless he actually has something to tell us" (V29/Q34).

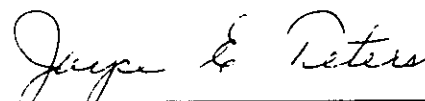
However, upon entering the AOR, the flight lead picked up a radar hit and reported the contact to AWACS. The wingman testified that AWACS responded with "Clear there" (V28/Q13). The F-15C flight lead commented, "AWACS basically acknowledged that he heard me, but that he had no information about this" (V29/Q37). Both pilots then initiated the process of determining whether the radar contact was friend or foe. The F-15C wingman stated, "I rolled my radar down, found a single low target... I locked onto it and interrogated both Modes I and IV with no reply" (V28/Q13). The F-15C flight lead made three attempts to interrogate the radar contact. He said, "At this point I continue to hold my radar lock and I use my air-to-air interrogator to interrogate the friendly modes that all aircraft should be squawking out there. The first one is Mode I... I interrogate and I get no response. I reached down and changed my switch to auto. Auto is going to use the S1/S2 switch... which is the second thing that all friendlies should be squawking... as soon as I initially push down on the interrogator button to interrogate Mode IV... the contact is locked. He's a star out there. If he was squawking proper Mode IV the star would change to a circle. Okay, if he wasn't, the star would stay a star. Initially, when I pressed down on the air-to-air interrogator, that star did turn to a circle. It lasted for about one second, and then the circle disappeared and went back to the star" (V29/Q33). The flight lead further related that there are anomalies with the jet that cause the initial interrogation to come up as a false reading. So he was unsure what the momentary circle meant, and decided to check again. He reinitiated interrogation and stated, "It [circle] only lasts for a second and then it goes away. For the remainder of the interrogation, 4 to 5 seconds, it's a star, and it's showing me that he's not squawking Mode IV" (V29/Q35).

Flight lead then tried a second time and reported "...there's no replies on any of their squawks in the interrogations. So, as far as I know, he's not squawking a friendly mode" (V29/Q37). Finally the F-15C flight lead made a third check and that checked negative (V29/Q35). AWACS responds with "Hits there" (V28/Q13).

At this point, the flight lead believed he was the first aircraft into the AOR, he knew of no friendly helicopter activity scheduled for that day in the AOR, the AWACS hadn't indicated anything to the contrary and he received no response he considered valid from the helicopters when he interrogated whether they were friend or foe. So now the F-15C flight lead is committed to a visual identification of the aircraft.

Flight lead states, "What I see is a Hind Helicopter. ...it had a tapered empinnage... the tail section from the bubble part to the tail is tapered, it gets slimmer as it goes back. The vertical tail is sloped so it goes backwards. It doesn't go straight up in the air... it's slanted towards the rear of the aircraft, the vertical tail. He has sponsons on both sides...it's the part... that they attach there... to put ordnance on. I say on the radio, VID Hind, no Hip... disregard Hip, VID Hind" (V29/Q38). Following his visual identification, the flight lead asked his wingman to confirm his ID. His wingman responded, "Tally Two" (V28/Q13). The F-15C flight lead stated "...I was positive of the aircraft I was looking at, but I was not sure that I was saying the right designation for it" (V29/Q33). "...With the sponsons and the tail section of the aircraft, I was definite, it was a Hind" (V29/Q42).

Regarding information from AWACS provided to the F-15C flight lead during the intercept, the flight lead replied, "The only information I received was on initial contact, I knew he heard me because he answered me, but gave no information back. On the second contact, the second time I made the radio call about the contacts he said, 'hits there', so I know he had them on his radar. And the rest of the transmissions were all acknowledging the fact he heard me, but without any additional information" (V29/Q111).



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TAB O

ADDITIONAL SUBSTANTIATING DATA REPORTS

	O-1
	O-2
O-1 UH-60 Black Hawk 88-26060	O-3
O-2 UH-60 Black Hawk 87-26000	O-4
O-3 E-3B AWACS	O-5
O-4 F-15C 79-0025	O-6
O-5 F-15C 84-0025	O-7
O-6 Human Factors	
O-7 Medical Reports	
O-8 Optics Report	
O-9 Crash Site Analysis Technical Report	
O-10 Technical Report, F-15C IFF/AAI Systems	
(See also Classified Addendum)	
O-11 Technical Report UH-60 Black Hawk	
IFF/AAI Systems	

TAB O-7

MEDICAL REPORTS

O-7a

O-7a Medical Summaries on Aircrews

O-7b Optometry Consultation, Control Witness 25

O-7c Ophthalmology Consultation, Control Witness 25

MEDICAL STATEMENT
USAF AIRCREW MEMBERS
BLACK HAWK ACCIDENT, 14 APRIL 1994

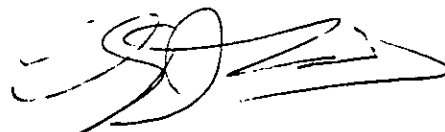
For each of the individuals listed at attachment 4, I conducted a review of the medical and dental records. All members had current flying class physicals and all were qualified for flying duties. Several individuals were on waivers for medical conditions and some were on medications for those conditions; none which impacted this accident.

Full physical examinations, including full eye and hearing tests, were performed on all members (Atch 5). Full optometric examinations were performed on Control Witness 26 (F-15C flight lead) and Control Witness 25 (F-15C wingman). Additionally, Control Witness 24 (AWACS TAOR controller) underwent the Farnsworth D-15 color test.

Urine and blood specimens were obtained on 14 APR 94 for drug screen, carbon monoxide, blood count, blood sugar and blood alcohol on Control Witness 09 (AWACS staff mission crew commander), 24 (AWACS TAOR controller), 25 (F-15C wingman) and 26 (F-15C flight lead) (Atch 5). Urine and blood specimens were obtained on 17 APR 94 for drug screen, carbon monoxide, blood count and blood sugar on the rest of the individuals (Atch 2, 7 and 8).

Complete psychosocial interviews, including 72 hour and 14 day histories, were conducted with each of the individuals, except Control Witnesses 09 (AWACS mission crew commander), 13 (AWACS enroute controller), 23 (AWACS duke) and 24 (AWACS TAOR controller). Counsel for Control Witness 23 limited the interview to the 24 hour period prior to the accident which revealed poor nutrition. Counsel for Control Witnesses 09, 13 and 24 recommended that their clients not participate in this interview. For these four individuals, interviews with associates were conducted to amplify or provide information concerning their psychosocial background and 72 hour history. Crew rest was reviewed for all individuals and no deficiencies were noted (Atch 4). Several crew members were TDY for four or more months in the previous 12 month period (Atch 6). The International Civil Aviation Organization's formula for recommended crew rest due to circadian rhythm desynchrony resulted in a rest time of 1.8 days (Atch 9).

With the exception of the matters noted in Attachment 1, 2 and 3, I saw no evidence of compromising mental or physical defect from review of records, physical exam results, toxicological reports and interviews.



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Accident Board Flight Surgeon

TECHNICAL REPORT
MEDICAL ATCH #1

1. A physical examination performed on Control Witness 17 (AWACS-AST) on 20 Apr 94 showed his distant visual acuity was 20/70 in both eyes without glasses. His near visual acuity was 20/20 in both eyes. He was not wearing, nor did he have, glasses on 14 Apr 94. He was able to perform his job reading the radar scope which is within arm's distance, since his near visual acuity was normal.
2. This condition did not impact this accident.



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**TECHNICAL REPORT
MEDICAL ATCH #2**

1. Urine toxicological screen for drugs on Control Witness 20 (AWACS-computer technician) performed by the Armed Forces Institute of Pathology was positive for pseudoephedrine (decongestant) and phenylpropranolamine (antihistamine). Control Witness 20 denied taking any medication except Excedrin P.M. (tylenol and benadryl) in the two weeks prior to the collection. He also was not prescribed any of these medications by a physician during this time. He denied any cold symptoms or fatigue, and flew six times in the previous two weeks without incident. The remainder of his drug screen was negative.

2. This finding did not impact this accident.




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TECHNICAL REPORT
ATCH #3

1. Control Witness 25 (F-15C pilot) had a condition that resulted in slowly progressive eyelid droop. He was evaluated by an ophthalmologist (eye doctor) on 7 APR 93 where he had 3 mm of right eyelid droop. He was given the option of surgery, but opted not to have it because the droop was not as severe as it became later. His flight physical on 17 MAY 93 noted "mild eyelid ptosis (droop) bilaterally (both eyes)." His most recent flight physical, performed on 14 Feb 94, made no comment regarding his eyes except that he had 20/20 visual acuity in both eyes, near and far, without correction.

2. A physical examination performed on Control Witness 25 on 18 Apr 94 was notable for right eyelid droop. His distant visual acuity was 20/15 in his right eye and 20/17 in his left eye, without correction. His near visual acuity was 20/30 in his right eye and 20/25 in his left eye, without correction (acceptable near vision for F-15C pilots). A full optometric exam performed on 24 APR 94 revealed some upper/outer visual field constriction in his right eye and minimal extreme upper field constriction in his left eye due to eyelid droop (Tab O-7b) He was then evaluated by an ophthalmologist at Landstuhl Hospital. Control Witness 25 had 7 mm of right eyelid droop and 3 mm of left eyelid droop. Visual field testing indicated normal fields in his left eye and visually significant eyelid droop affecting his upper fields in his right eye (Tab O-7c).

3. The constriction did not affect his central vision which is the sole source of sharp visual acuity. Central vision is the type of vision an individual would use to attempt specific recognition of an object, such as an aircraft. He was not qualified for flying class II duties IAW AFR 160-43 due to abnormal visual fields in his right eye. He was able to see all the instruments and lights in the F-15C. This defect appeared to have no impact on the mishap.



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TECHNICAL REPORT
 MEDICAL ATCH #4
 CREW REST - TIME IN ZULU
 CONTROL WITNESSES 2 - 26

<u>Control Witness #</u>	<u>Left Work-13 APR</u>	<u>Asleep-13 APR</u>	<u>Awoke-14 APR</u>	<u>Duty-14 APR</u>
2	No work	1800	0130	0310
3	0530	1800	0200	0310
4	1330	2000	0100-0200	0310
5	No work	1900	0230	0310
6	1230	1800	0230	0310
7	0815	1900	0200	0310
8	No work	1830	0100	0310
9	0900	1730	unknown	0310
10	1530	1800	0220	0310
11	0900	1730	0240	0310
12	1200	1700	0200	0310
13	0900	unknown	unknown	0310
14	1200	2000	0130	0310
15	0800	1630	0230	0310
16	0900	1830	0200	0310
17	0830	1800	0200	0310
18	0900	1930	0220	0310
19	0700	1700	0230	0310
20	No work	1900	0230	0310
21	0900	1900	0230	0310
22	No work	1900	0230	0310
23	1330	1900	0230	0310
24	0900	unknown	unknown	0310
25	1230	2100	0330	0420
26	0800	2030	0330	0420

TECHNICAL REPORT
MEDICAL ATCH #5

DATES OF PHYSICAL
EXAMINATIONS AND SPECIMENS

<u>Control Witness #</u>	<u>Date of Physical</u>	<u>Date of Blood/Urine Specimen</u>
2	21 APR	17 APR
3	21 APR	17 APR
4	24 APR	17 APR
5	21 APR	17 APR
6	21 APR	17 APR
7	24 APR	17 APR
8	24 APR	17 APR
9	19 APR	17 APR
10	19 APR	14 APR
11	20 APR	17 APR
12	19 APR	17 APR
13	19 APR	17 APR
14	20 APR	17 APR
15	21 APR	17 APR
16	21 APR	17 APR
17	20 APR	17 APR
18	20 APR	17 APR
19	24 APR	17 APR
20	24 APR	17 APR
21	21 APR	17 APR
22	24 APR	17 APR
23	19 APR	17 APR
24	20 APR	14 APR
25	18 APR	14 APR
26	18 APR	14 APR

TECHNICAL REPORT
MEDICAL ATCH #6

TDY TIME

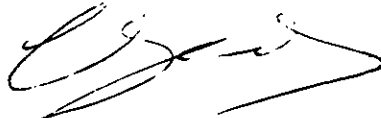
1. The psychosocial interviews revealed TDY periods of four or more months in the previous 12 month period in the following individuals:

Control Witness 4: four months
Control Witness 6: 180 days
Control Witness 11: 45% in last 12 months
Control Witness 12: 50% in last 12 months
Control Witness 14: Little less than 5 months
Control Witness 15: 200 days
Control Witness 18: 120 days
Control Witness 21: 4-5 months

2. Although there were negative comments about the frequency of TDYs, no one noted current marital difficulties, mental or physical problems relating to the TDYs.

3. Several weapons directors also noted that the TDYs tended to lessen their skills particularly the drug interdiction TDYs.

4. This finding did not impact their mental or physical well-being.



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TECHNICAL REPORT
MEDICAL ATCH 7


1. Urine toxicological screen for drugs on Control Witness 06 (AWACS-pilot) performed by the Armed Forces Institute of Pathology was positive for promethazine (anti-nausea agent). Control Witness 06 had no difficulties with gastrointestinal problems until after 14 April 1994. He was hospitalized two days after 14 April 1994 and given this medication at that time by a physician. The remainder of his drug screen was negative.
2. This finding did not impact this accident.



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TECHNICAL REPORT
MEDICAL ATCH 8

1. Urine toxicological screen for drugs on Control Witness 12 (staff weapons director) performed by the Armed Forces Institute of Pathology was positive for pseudoephedrine (decongestant) and chlorpheniramine (antihistamine). Control Witness 12 discontinued taking these medications at least two days prior to 14 April 1994. He denied taking any medication after he was returned to flying status at that time. The remainder of his drug screen was negative.
2. This finding did not impact this accident.



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**TECHNICAL REPORT
MEDICAL ATCH #9**

CIRCADIAN RHYTHM

1. Psychosocial interviews and 72-hour and 14-day histories revealed low grade circadian rhythm desynchrony in all AWACS crewmembers except the staff mission crew commander, staff weapons director, air surveillance officer, computer technician and the ACE. No individual complained of fatigue or any ill effects on the morning of the 14 April 1994 flight.
2. With the exception of the individuals noted above, the crew departed Oklahoma City, Oklahoma on 10 April 94 at 1300Z (0800 local) and arrived in Incirlik AB, Turkey on 11 April 94 at 1100Z (1400 local).
3. The International Civil Aviation Organization formula for recommended crew rest due to circadian rhythm desynchrony is found on the subsequent pages of this attachment (pages III-37-39). Using 8 time zones between Incirlik, Turkey and Oklahoma City, Oklahoma and the above takeoff and landing times, the calculations for this crew result in 1.8 days of rest time.



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(12) Do not nap if you're experiencing insomnia. Napping will just make sleeping later more difficult.

(13) Separate sleeping and studying/reading areas. You will have difficulty falling asleep if you study/read near your bed, or you may have difficulty staying alert when you're trying to study/read.

(14) Consider ear plugs.

(15) Take a hot bath about 2 hrs before retiring. Sleep occurs and deepens as body temperature falls.

(16) When all else fails, try warm milk!

3. Circadian rhythm ("jet lag fatigue")

Perhaps the most obvious contributor to stress in the new travel style is the circadian dysrhythmia that lands the aircraft crewmember/traveler in a different diurnal time from which he departed.

Data suggest that psychologic and physiologic effects may be temporarily serious for an individual immediately involved in significant decisions before becoming adjusted to a time zone change. Psychological adjustment occurs fairly rapidly, but physiologic functions, including the sleep/awake cycle, digestion of food, body temperature, pulse rate, kidney function, hormone levels, alertness, and fatigue operate according to "circadian rhythm" associated with usual day-night cycle. An appreciable rest period is required for the traveler to readjust his rhythms to several days' residence in a new time zone 4 or more hours from his previous time zone.

There is great individual variability in the effects of time zone changes and in one's speed of adjustment, especially in the sleep/awake cycle. The young adjust more easily, older individuals more slowly. All activities during the initial period of overseas rephasing should be paced deliberately so that stresses are kept to a minimum.

The single most essential requirement is to obtain carefully planned sleep and rest during the first 24 hrs. Meanwhile, decision-making is impaired and travelers unaware of this phenomenon may make errors of judgment. An eastward daytime

CERTIFICATION OF EXTRACT <i>from Flight</i>	
I reviewed <i>Circadian Rhythm Extract Surgery manual</i>	
From that source document, I extracted the information contained in this extract. I certify the information contained herein is a true and accurate extract of that source document.	
<i>11 MAY 74</i>	<i>[Signature]</i> Signature
Date	<i>MAT Chris Lisanti / 444051SC+</i> Name/Organization/Section

Tab 0-7a
A4c4 9
EJL

flight to Europe should be followed by a good night's sleep before scheduled activities. An eastward nighttime flight calls for a morning nap, a leisurely afternoon, and early to bed that night.

Conversely, going from east to west, the traveler literally races the sun across the sky and arrives at his destination with local time much the same as the time of departure. The many hours of elapsed time make a long day; early retirement and a long sleep are essential. If the traveler is returning to home base of customary residence, whether moving to the east or especially to the west, the resynchronization is usually more rapid but still requires a rest period.

The International Civil Aviation Organization (ICAO) has evolved a travel-time formula to help ensure that disturbance in circadian rhythm neither works a hardship nor impairs cerebral function on trips to distant places. Enlightened policies of this type are being adopted by the management of progressive organizations and corporations, ensuring optimum efficiency on the part of their traveling representative. The immediate and long-range benefits to the parent organization may not be apparent at first, but they have a sound biological basis. The benefit to the traveler, in terms of lessening fatigue, of the use of formulas such as that used by the ICAO is obvious. The ICAO formula is as follows:

$$\begin{aligned} \text{Rest period in tenths of days} &= \frac{\text{Travel time (hrs)}}{2} \\ &+ \text{Time zones in excess of 4} + \\ &\text{Departure time coefficient (local time)} + \\ &\text{Arrival time coefficient (local time)} \end{aligned}$$

The departure (DTC) and arrival time coefficients (ATC) are given in the following table.

<u>Period (hours)</u>	<u>DTC</u>	<u>ATC</u>
0800-1159	0	4
1200-1759	1	2
1800-2159	3	0
2200-0059	4	1
0100-0800	3	3

The increased weight given the later hours for departures helps compensate for the effects of loss of sleep. Also, the high ATC for the period

0800-1159 helps compensate for disruptions experienced during early morning flights plus the effect of arriving at the beginning of a workday without sufficient rephasing of the circadian rhythms. The amount of phase difference is accounted for in the formula by the term "time zones in excess of 4." In applying the formula, the following rules are observed by ICAO.

a. The value obtained for rest period, in tenths of days, is to be rounded to the nearest higher half-day. Rest stops that add up to less than a day before rounding will not be scheduled unless the journey involves an overnight flight on mission travel.

b. "Travel time, in hours" means the number of hours of elapsed time required for the journey, rounded off to the nearest hour.

c. "Time zones" are computed in increments of 15 degrees of longitude from Greenwich.

d. "Departure time" and "arrival time" are local times.

4. Nutrition

Good nutrition is essential for continued effective duty performance. The FS can serve as a source of information and include nutrition topics in periodic discussions with flyers. Diet guidelines are available in the references listed below.

a. Several formulas are available for calculating a balanced diet. (The following calculation examples use 150 lbs as ideal weight sample.)

(1) To calculate basic caloric requirements, take ideal weight and multiply by 10, adjusting for age and activities.

$$150 \times 10 = 1500 \text{ cal/day}$$

(2) Carbohydrates: To prevent ketonuria, a minimum of 1 gm /lb of body weight is required.

$$150 \text{ gm CHO/day} \times 4 \text{ cal/gm} = \\ 600 \text{ cal/day as CHO}$$

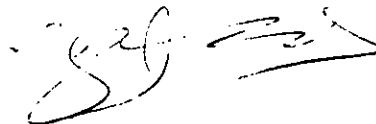
**MEDICAL STATEMENT
UH-60 BLACK HAWK CREWMEMBERS
BLACK HAWK ACCIDENT, 14 APRIL 1994**

For each of the individuals listed below, I conducted a review of the medical and dental records and found that all individuals had current flying class physicals and all were qualified for flying duties. All were on chloroquine for malaria prophylaxis without difficulties.

The Armed Forces Institute of Pathology conducted autopsies on all individuals and found no pre-existing disease. "Submarining" injuries were found in all crewmembers and passengers indicating that all were in seat belts upon impact. Toxicologic screens for drugs and alcohol were performed and all were negative.

Interviews with associates were conducted to obtain psychosocial background and 72 hour histories (Atch 1 for crew rest).

I saw no evidence of compromising pre-existent mental or physical defect from review of records, autopsy reports and toxicologic results.



**CHRISTOPHER J. LISANTI
MAJ, USAF, MC, FS
Accident Board Flight Surgeon**

AIRCREW REST-BLACK HAWK HELICOPTERS
TIME IS IN ZULU

<u>Name</u>	<u>Left work</u> <u>13 APR</u>	<u>Asleep-13 APR</u>	<u>Awoke-14 APR</u>	<u>Duty-14 APR</u>
McKenna, Patrick M.	Unknown	Unknown	Unknown	0315
Hall, Michael A.	No work	Unknown	Unknown	0315
Garrett, John W., Jr.	1415	1830	Unknown	0315
Mounsey, Erik S.	1430	Unknown	Unknown	0315
Bass, Cornelius A.	1530	Unknown	0200	0315
Colbert, Jeffrey C.	1500	1830	0230	0315
Ellner, Mark A.	1500	Unknown	0215	0315
Robinson, Michael S.	1530	Unknown	0200	0315

TAB O-7

MEDICAL REPORTS

O-7a Medical Summaries on Aircrews

O-7b Optometry Consultation, Control Witness 25

O-7c Ophthalmology Consultation, Control Witness 25

O-7a

O-7b

DEPARTMENT OF THE AIR FORCE
UNITED STATES AIR FORCES IN EUROPE

MEMORANDUM FOR: Individuals Concerned

16 May 1994

FROM: 39 MG/SGHO (Major Gentilman)

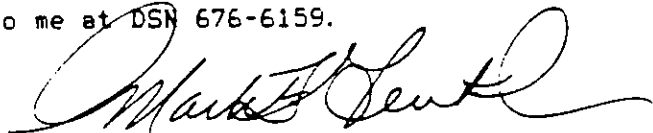
SUBJECT: Summary of Eye Exam - [REDACTED]

1. An eye examination was performed on [REDACTED] on 24 April 1994.
A summary of the findings are as follows:

Vision: 20/20 in each eye at twenty feet and sixteen inches
Dominant Eye: Left Eye
External Exam: Pupils were equal in diameter, round and reactive to both light and focusing effort; There was no Marcus Gunn pupil (signifies no disease of the optic nerve); There was a slight droop to the right eyelid covering the top 1 mm of the pupil in dim illumination, the pupil was not involved in normal illumination; full range of motion to both eyes representing normal eye muscle function; depth perception was to 40 sec of arc which was the maximum on this test; color vision by pseudoisochromatic plates (standard military test) was normal in both eyes; phorias (represent balance of the two eyes together) was normal horizontally and vertically; Amsler Grid was normal (measuring central visual field)
Subjective Refraction: No prescription necessary to achieve 20/20
Slit Lamp Evaluation: Eyes were quiet and white. Very slight irritation to the cornea inferiorly in both eyes which does not interfere with vision or comfort
Visual Field (Humphries 246 point full field test): Some superior-temporal field reduction corresponding to the eyelid droop in the right eye and the left eye had a slight extreme superior field reduction corresponding to a minimal lid lag in the left eye. Overall considered unremarkable. Central field clear without restriction or blind spots
Ophthalmoscopy: (through dilated pupil) retina flat to the ora serrata without holes or tears; Cup disc ratio .1 horizontally and vertically; arteriole/vein ratio 2/3; the fovea and media were clear

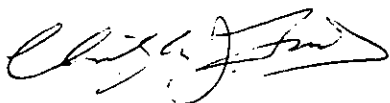
Impression: normal ocular health/vision; mild lid droop secondary to aging changes of the skin around the eye (right eye slightly more than the left). Visual field changes not significant since the visual field test is done in dimmer than average illumination. No superior loss was noted or expected in normal or daylight illumination.

2. Questions may be directed to me at DSN 676-6159.



MARK F. GENTILMAN, Major, USAF, ESC
Chief, Optometry Services

* Control Witness = 25



CERTIFICATE
I certify that I am the Records Custodian for the Accident Investigation Board convened to investigate the crash of two U.S. Army Black Hawk helicopters in the no fly zone in northern Iraq on 14 April 1994, and that this is a true and accurate copy of the record which is kept in my records system.
13 May 94
WILLIAM L. HARRIS, Capt, USAF, MSC
Evidence Custodian, Incirlik Air Base, Turkey

HEALTH RECORD | CHRONOLOGICAL RECORD OF MEDICAL CARE

DATE | SYMPTOMS, DIAGNOSIS, TREATMENT, TREATING ORGANIZATION (Sign each entry)

APR 24 1994

39 TACG HOSPITAL (USAF)
OPTOMETRY CLINIC/SGH 0 5) to mltc here for evaluation
INCIRLIK AB, TU
APO AE 09824 0) no rx nct OD 18 →

PD 66 | 13

Using visor, no sunglasses OS 15
at time of incident. Renewed visual problems.

⊙ VA 5 Fc OD 20/20 J, @ 16"
OS 20 J,

OS: Dominant Eye

Ext: PERC(-) MG, slight ptosis OD, ~~Att~~ ¹⁶ ≈ 1mm pupil involvement w dim illumination, Full EOM, CT(D)φ, Stereo 40 sec arc, no misses; Color (PIP) all 14 correct.

Phoria @ 20': orthophoria & no vertical phoria
16': 2^d exophoria & no vertical phoria

July OD pl sph 70/20 Amsterlund OU
OS pl sph 20

SE: eyes quiet/white; minimal inferior stippling (1-2 areas) OU. Cornea/Lens(-) OK
Visual fields (Humphries 24-2 full field):
Some superior-temporal loss 2° to ptosis OD, OS has minimal but present extreme superior field reduction.

PATIENT'S IDENTIFICATION (Use this space for Mechanical Imprint)

RECORDS MAINTAINED AT:		
PATIENT'S NAME (Last, First, Middle Initial)		SEX
* [REDACTED]		m
RELATIONSHIP TO SPONSOR	STATUS	RANK/GRADE
S	AD	[REDACTED]
SPONSOR'S NAME		ORGANIZATION
S		[REDACTED]
DEPART./SERVICE	SSN/IDENTIFICATION NO.	DATE OF BIRTH
AF	[REDACTED]	[REDACTED]

CHRONOLOGICAL RECORD OF MEDICAL CARE | STANDARD FORM 800 (REV. 5-84)
Prescribed by GSA and ICMR
FIRM (41 CFR) 201-45.505

CERTIFICATE
I certify that I am the Records Custodian for the Accident Investigation Board convened to investigate the crash of two U.S. Army Black Hawk helicopters in the no fly zone in northern Iraq on 14 April 1994, and that this is a true and accurate copy of the record which is kept in my records system.
11 May 94
Date
W. L. H.
WILLIAM L. HARRIS, Capt, USAF, MSC
Evidence Custodian, Incirlik Air Base, Turkey

Reduced - will
* Control business 25
[Signature]

DATE

SYMPTOMS, DIAGNOSIS, TREATMENT, TREATING ORGANIZATION (Sign each entry)

Central fields clear $\bar{5}$ restriction or
scotoma.

Oph (dilated $\bar{1}^{\circ}$ Mydracyl / 2.5% Neosynephrine)
OD . 1/1 OS . 1/1 SW 93, fovea,
media clear OU. Retina flat $\bar{5}$ holes or
tears seen OU

- ① emmetropia, excellent uncorrected vision
- ② normal ocular health OU
- ③ mild dermatochalasis OU $\bar{2}^{\circ}$ ptosis
resulting in some sup-temp field loss
OS & minimal extreme ^{superior} loss OS.
- ④ Return to Maj. Lisanti as directed

MARK E. GENTILMAN, MAJ, USAF, BSC
AFSC 9256

Chief, Optometry Services
39TACG Hospital/Incirlik AB, TU.

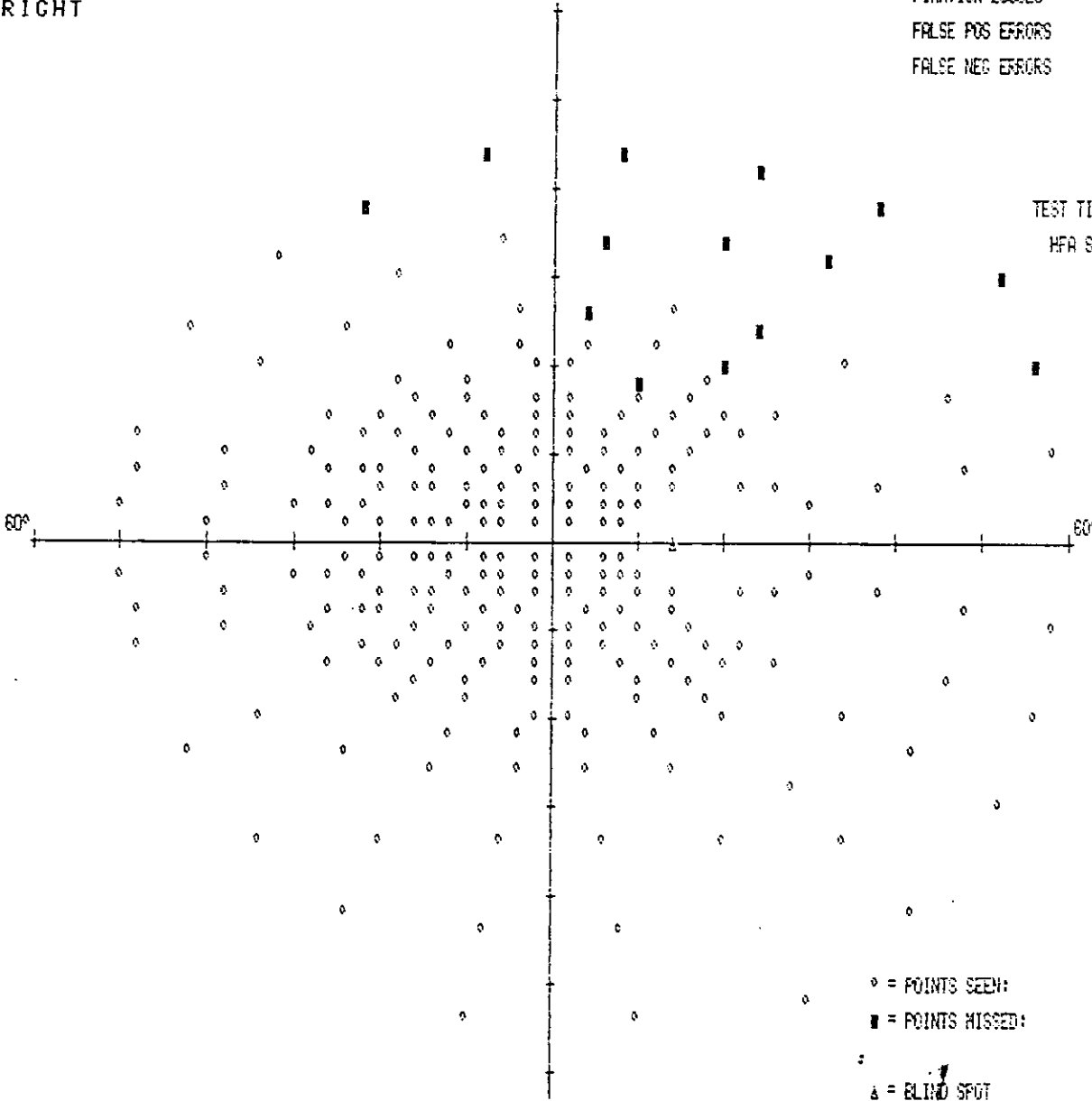
FULL FIELD 246 POINT SCIENTIFIC TEST

STIMULUS III, WHITE, BCKGND 31.5 ASB NAME [REDACTED]
 BLIND SPOT CHECK SIZE III ID [REDACTED] BIRTHDATE [REDACTED]
 FIXATION TARGET CENTRAL DATE 24-04-94 TIME 14:12:12
 STRATEGY THRESHOLD RELATED PUPIL DIAMETER VA 20/20
 CEN 34 DB PER 34 DB RX USED DS OCK DEG

RIGHT

FIXATION LOSSES 0/27
 FALSE POS ERRORS 0/14
 FALSE NEG ERRORS 0/10

TEST TIME 00:12:15
 HFR S/N 640-2417



○ = POINTS SEEN: 232/246
 ■ = POINTS MISSED: 14/246
 ▲ = BLIND SPOT

GRAYTONE SYMBOLS

REV 5.3

SYM										
ASB	.8 to .1	2.5 to 1	8 to 3.2	25 to 10	79 to 32	251 to 100	794 to 316	2512 to 1000	7943 to 3162	2 to 10000
DB	41 to 50	36 to 40	31 to 35	26 to 30	21 to 25	16 to 20	11 to 15	8 to 10	1 to 5	20

DR. GENTILMAN
 INCIRLIK
 TSGT GREG P BEEKS

ALLERGAN
 HUMPHREY

* Control Witness = 25

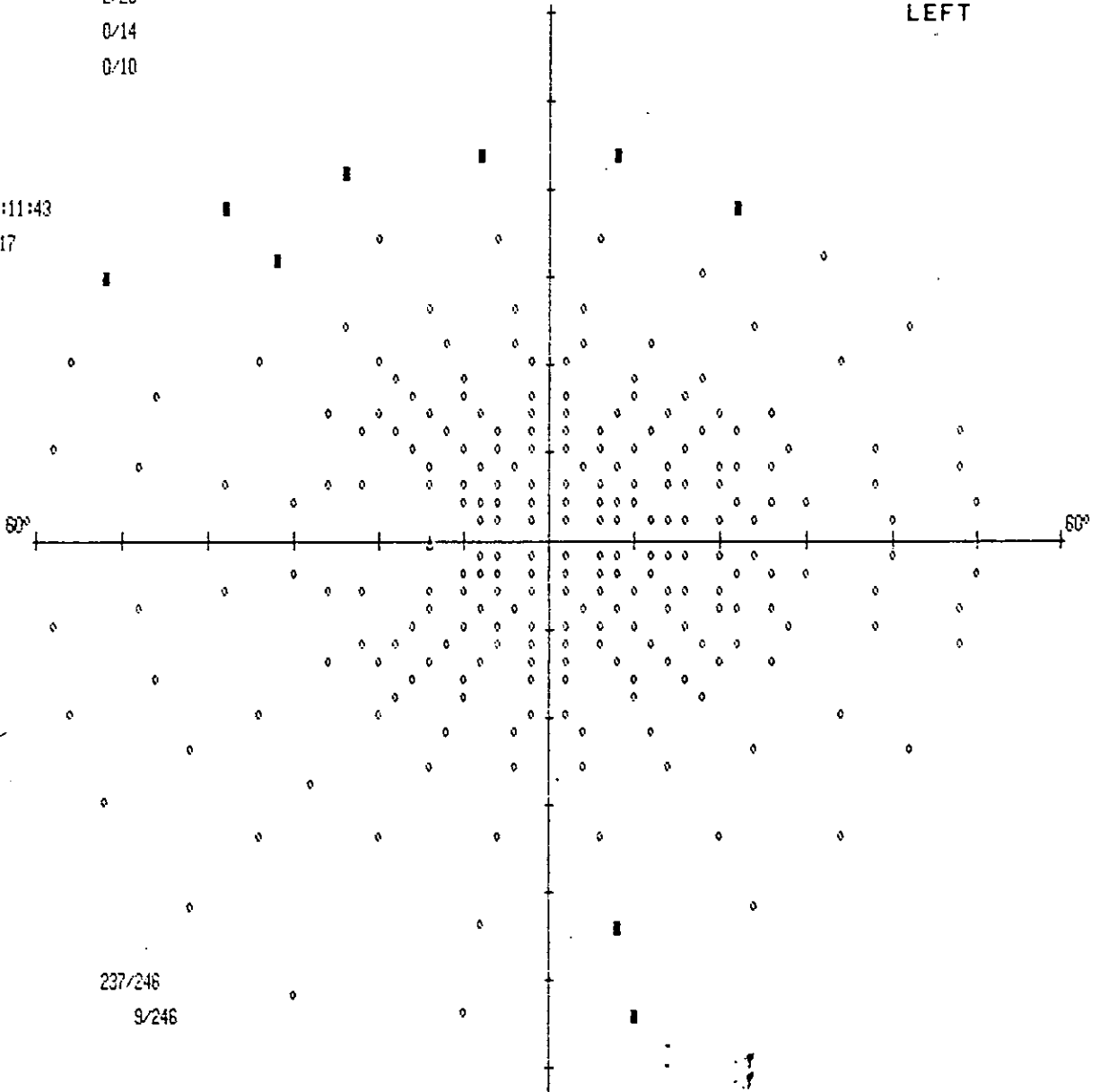
FULL FIELD 246 POINT SCREENING TEST

STIMULUS III, WHITE, BCKGND 31.5 ASB NAME * [REDACTED]
 BLIND SPOT CHECK SIZE III ID [REDACTED] BIRTHDATE [REDACTED]
 FIXATION TARGET CENTRAL DATE 24-04-94 TIME 14:27:47
 STRATEGY THRESHOLD RELATED PUPIL DIAMETER VA 20/20
 CEN 34 DB PER 34 DB RX USED DS BOX DEG

FIXATION LOSSES 2/28
 FALSE POS ERRORS 0/14
 FALSE NEG ERRORS 0/10

LEFT

TEST TIME 00:11:43
 HFA S/N 640-2417



° = POINTS SEEN: 237/246
 ■ = POINTS MISSED: 9/246
 Δ = BLIND SPOT

GRAYTONE SYMBOLS

REV 5.3

DR. GENTILMAN
 INCIRLIK
 TSGT GREG P BEEKS

SYM	[Symbol 1]	[Symbol 2]	[Symbol 3]	[Symbol 4]	[Symbol 5]	[Symbol 6]	[Symbol 7]	[Symbol 8]	[Symbol 9]	[Symbol 10]
ASB	.8 to .1	2.5 to 1	8 to 3.2	25 to 10	79 to 32	251 to 100	794 to 318	2512 to 1000	7943 to 3182	2 to 10000
DB	41 to 50	36 to 40	31 to 35	28 to 30	21 to 25	18 to 20	11 to 15	6 to 10	1 to 5	20

ALLERGAN
 HUMPHREY

* Control w. loss = 15
[Signature]

TAB O-7

MEDICAL REPORTS

O-7a Medical Summaries on Aircrews

O-7a

O-7b Optometry Consultation, Control Witness 25

O-7b

O-7c Ophthalmology Consultation, Control Witness 25

O-7c

MEMORANDUM FOR RECORD

To whom it may concern:

I examined Control Witness #25 on 5 May 1994 who had the following ophthalmic examination findings:

His history was significant only for Ehlers-Danlos Syndrome. No other eye history was elicited.

On ocular exam,

Vision was 20/20 or better in each eye

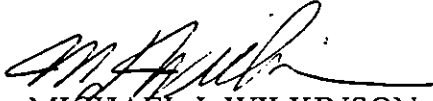
Pupils and motility were normal

Anterior segment exam revealed only prominent brow ptosis

Funduscopy exam was normal

His exam boiled down to his prominent brow ptosis, or drooping, which caused a significant superior visual field defect when tested. His central vision in the same eye was perfectly normal (actually better), but any object (or part of an object) greater than 5 degrees above the horizontal would be occluded from view. This would only be significant if he was only using that eye, since his other eye is perfectly normal in both central vision and visual field. CR

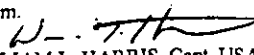
My impression is that this condition should not adversely hamper his normal vision, as long as both eyes are being used to view an object. There may, however, be some loss of depth perception if the object is only being viewed by the normal eye; but recognition of an object should not be hampered.


MICHAEL J. WILKINSON
MAJ, USAF, MC
Ophthalmologist

CERTIFICATE

I certify that I am the Records Custodian for the Accident Investigation Board convened to investigate the crash of two U.S. Army Black Hawk helicopters in the no fly zone in northern Iraq on 14 April 1994, and that this is a true and accurate copy of the record which is kept in my records system.

19 May 94
Date


WILLIAM L. HARRIS, Capt, USAF, MSC
Evidence Custodian, Incirlik Air Base, Turkey

MEDICAL RECORD

CONSULTATION SHEET

REQUEST

TO: Ophthalmology (Dr. Wilkinson) FROM: (Requesting physician or activity) FSO (Geyer) DATE OF REQUEST 4 May 94

REASON FOR REQUEST (Complaints and findings)
Complete ophthalmologic exam. Eptosis on visual fields as related to ptosis (Ehler-Danlos Synd.).

PROVISIONAL DIAGNOSIS
Ptosis - O.D.

DOCTOR'S SIGNATURE <u>[Signature]</u> DAVID E. GEYER, LTC, USAF, MC, FS	APPROVED	PLACE OF CONSULTATION <input type="checkbox"/> BEDSIDE <input checked="" type="checkbox"/> ON CALL	<u>1330</u> <u>5 May 94</u> <input type="checkbox"/> ROUTINE <input type="checkbox"/> TODAY <input type="checkbox"/> 72 HOURS <input type="checkbox"/> EMERGENCY
---	----------	---	--

DAVID E. GEYER, LTC, USAF, MC, FS
 AFSC 9356
 36th Medical Group Bitburg/SGP

sc 20/20 20/20 P: OPAD
COMI O.V.

sc 7mm brow ptosis. i satly proptose OD.
 3mm brow ptosis OS
 1.5mm VL ptosis O.V.
 K. clear w
 K. clear
 lens - n/c
 F: Normal MVD O.V.
 Normal lid closure & function O.V.
 S +25
 C +25
 GV: See attached VF's.

Imp Vis sig. brow ptosis O.D. No other ophthalmologic abn.
Re Consider surgl repair.

(Continue on reverse side)

SIGNATURE AND TITLE <u>[Signature]</u>	MICHAEL L. WILKINSON, Major, USAF, MC OPHTHALMOLOGY 9436	DATE <u>5 May 94</u>
IDENTIFICATION NO.	ORGANIZATION	REGISTER NO.
		WARD NO.

PATIENT'S IDENTIFICATION (For typed or written entries give: Name—last, first, middle; grade; rank; rate; hospital or medical facility)

ABAF

CERTIFICATE

I certify that I am the Records Custodian for the Accident Investigation Board convened to investigate the crash of two U.S. Army Black Hawk helicopters in the no fly zone in northern Iraq on 14 April 1994, and that this is a true and accurate copy of the record which is kept in my records system.

[Signature]
 WILLIAM L. HARRIS, Capt, USAF, MSC
 Evidence Custodian, Incirlik Air Base, Turkey

11 May 94
 Date

CONSULTATION SHEET
 Medical Record
 STANDARD FORM 513 (REV. 7-91)

SCHWIND

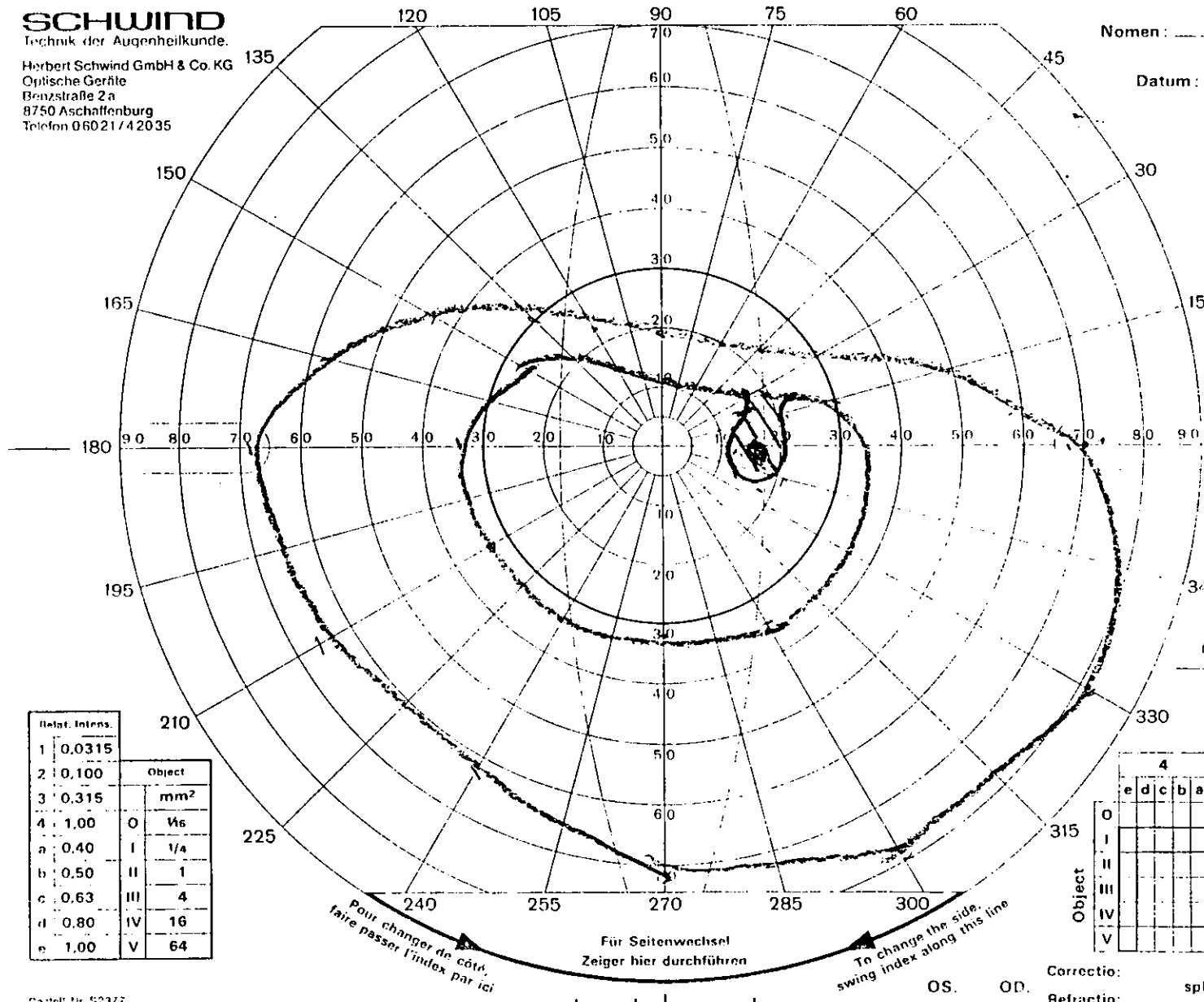
Technik der Augenheilkunde.
 Herbert Schwind GmbH & Co. KG
 Optische Geräte
 Benzstraße 2a
 8750 Aschaffenburg
 Telefon 06021/42035

Nomen: _____

Datum: 5 May 94

*Good
 eye*

M/W



4 mm Diameter pupillae

Relat. Intens.	Object
1	0.0315
2	0.100
3	0.315
4	1.00
a	0.40
b	0.50
c	0.63
d	0.80
e	1.00

Object	mm ²
O	Vis
I	1/4
II	1
III	4
IV	16
V	64

Object	4				3				2				1							
	e	d	c	b	a	e	d	c	b	a	e	d	c	b	a	e	d	c	b	a
O																				
I																				
II																				
III																				
IV																				
V																				

Pour changer de côté, faire passer l'index par ici
 Für Seitenwechsel Zeiger hier durchführen
 To change the side, swing index along this line

Correctio: _____
 Refractio: sph 0 cyl _____
 OS. OD. Visus: _____

0.14.22% / hkh

SCHWIND

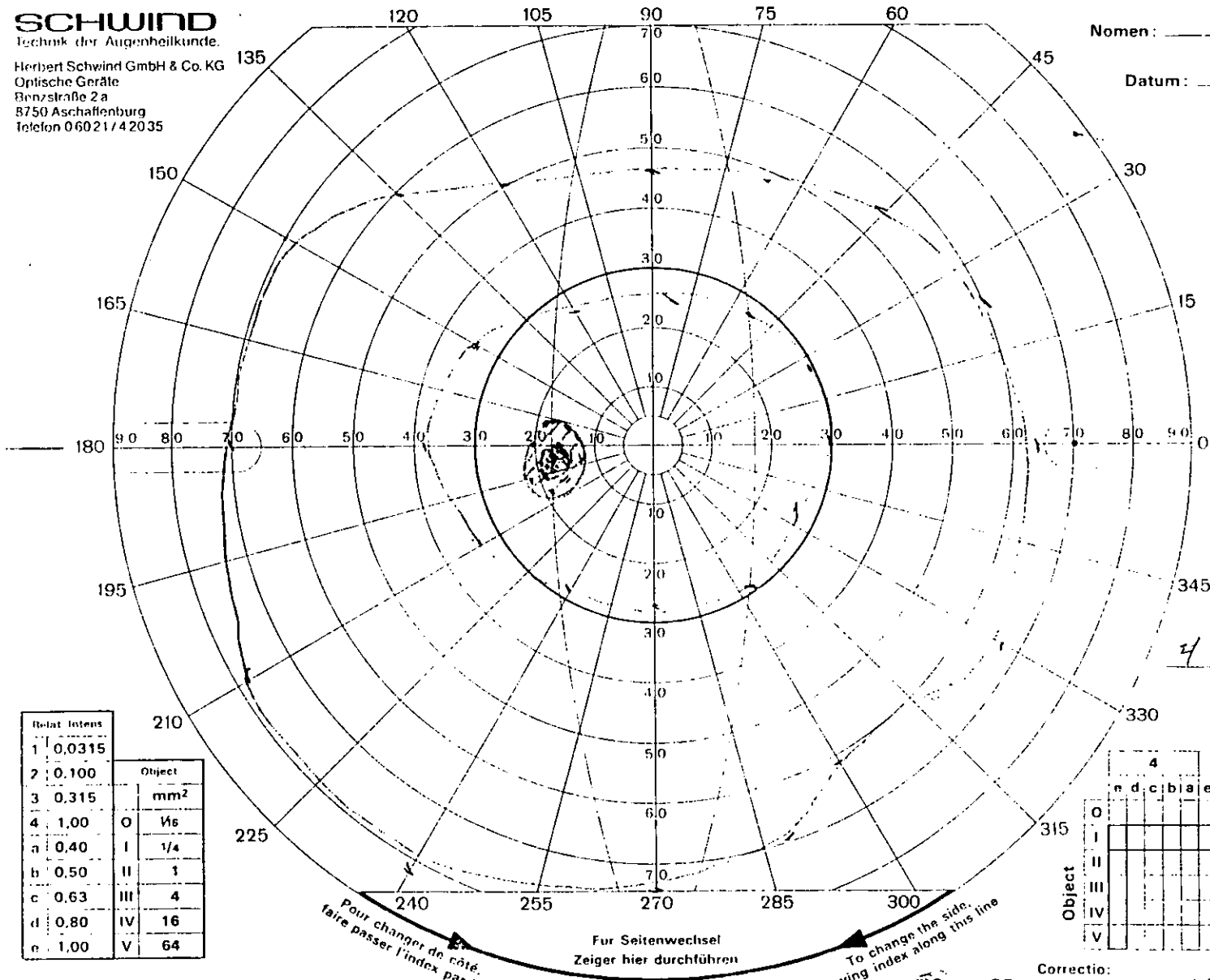
Technik der Augenheilkunde.
Herbert Schwind GmbH & Co. KG
Optische Geräte
Benzstraße 2a
8750 Aschaffenburg
Telefon 06021/42035

Nomen: _____

Datum: 5 May 94

Genel P & C

SMJW



4 mm Diameter pupillae

Relat Intens	Object
1 0.0315	mm ²
2 0.100	O 1/6
3 0.315	I 1/4
4 1.00	II 1
a 0.40	III 4
b 0.50	IV 16
c 0.63	V 64
d 0.80	
e 1.00	

Object	Relat. Intens.														
	4	3	2	1											
O	e	d	c	b	a	e	d	c	b	a	e	d	c	b	a
I															
II															
III															
IV															
V															

Pour changer de côté, faire passer l'index par ici.
Für Seitenwechsel Zeiger hier durchführen
To change the side, swing index along this line

Correctio: _____
Refractio: sph C cyl Visus: _____

Adjusted to 82% / all

TAB O

ADDITIONAL SUBSTANTIATING DATA REPORTS

	O-1
	O-2
O-1 UH-60 Black Hawk 88-26060	O-3
O-2 UH-60 Black Hawk 87-26000	O-4
O-3 E-3B AWACS	O-5
O-4 F-15C 79-0025	O-6
O-5 F-15C 84-0025	O-7
O-6 Human Factors	O-8
O-7 Medical Reports	
O-8 Optics Report	
O-9 Crash Site Analysis Technical Report	
O-10 Technical Report, F-15C IFF/AAI Systems	
(See also Classified Addendum)	
O-11 Technical Report UH-60 Black Hawk	
IFF/AAI Systems	

17 May 94

**TECHNICAL REPORT
HUMAN FACTORS VISION EVALUATION**

AIRCRAFT EVALUATED: Two UH-60 Black Hawk helicopters, serial numbers 88-26060 and 87-2600, and two F-15C fighter aircraft, serial numbers 79-0025 and 84-0025.

INCIDENT DATE: 14 Apr 94

I. INTRODUCTION: The purpose of this evaluation was to provide information concerning the physical and psychophysiological factors that influenced the visibility of the two UH-60 Black Hawk helicopters preceding the accident.

II. BACKGROUND: The accident involved the crash of two US Army Black Hawk helicopters, serial numbers 88-26060 and 87-26000, and the possible involvement of US F-15C fighter aircraft, serial numbers 79-0025 and 84-0025, and a US AWACS, aircraft serial number 77-0351, in the crash of these helicopters in the northern "no fly zone" of Iraq on 14 April 1994.

III. EVALUATION: This evaluation included: a) determining the visual angles of the Black Hawk aircraft and their US flag marker features and a Red Cross given three different flight geometries; b) determining the range of possible apparent contrasts of the Black Hawk aircraft against the northern Iraq terrain; c) predicting whether the Black Hawk aircraft and/or their Red Cross and US flag markers were above identification threshold given the different flight geometries and the visual acuities of the two F-15 fighter pilots; d) discussing the potential visual impact of wearing USAF-issued sun visors, and high-contrast "shooters" visors; and e) discussing the potential visual impact of optical distortions in aircraft canopy and visor material. The details of each of these components of our evaluation are specified in and listed as different subsections.

A. General Accident Human Factors Vision Information:

The following human factors vision information was given to us by the Accident Board to conduct our evaluations. The lead F-15C fighter aircraft is referred to as Fighter-1 (F-1), the trailing F-15C fighter aircraft is referred to as Fighter-2 (F-2). The UH-60 helicopters are referred as lead Black Hawk (BH-L) and trailing Black Hawk (BH-T).

Accident date and time: 14 Apr 94, 1130 hrs

Environmental Conditions: Clear sky, no haze, 18,228-meter visibility, 10^5 lux sun illuminance

Description of Terrain:

2463-ft MSL valley ridge within mountainous region (5-7-mile separation)

Green terrain with gray rocks (reflectance not specified, estimated to range between 7.6-10%)

Black Hawk Information:

Fuselage length = 50-ft, 7.5-in

- with main blades = 64-ft, 10.0-in

Fuselage width = 9-ft, 8.0-in

- with ESSS (auxiliary wing tank sponsons) = 20-ft, 2.0-in

Main rotor blade diameter = 53-ft, 8.0-in

Black/olive drab infrared suppressive paint (7.5% mean reflectance)

Approximate Altitude = < 300 - 500-ft AGL (200-ft AGL used for calculations)

Approximate Ground Speed = 130 knots

US Flag Marker Information:

Located on cabin door and auxiliary wing tank

Overall dimensions = 3-ft by 1-ft, 10-in

Blue portion dimensions = 1.5-ft by 1-ft

Star diameter = $1\frac{1}{8}$ -in

Distance between stars = $2\frac{5}{8}$ -in

5 rows of 6 stars and four rows of five stars in an offset pattern

Blue paint mean reflectance = 5.9%

Stripe dimensions = 3-ft by 1.75-in

13 alternating red and white stripes

Red paint mean reflectance = 32.2%

White paint mean reflectance = 92.1%

Red Cross Marker Information:

Located on the belly (1), top (1), nose (1), and doors (2)

Dimensions = 22-in by 22-in white field

Red stripe dimensions = 18-in by 6-in

White paint mean reflectance = 92.1%

Red paint reflectance = 32.2%

F-15C Fighter Aircraft Information:

Estimated ground speed = 450 knots

F-1 Aircraft Geometry (see Atch 1, Figure 1):

Altitude above Black Hawk = 500-ft (F-1)

Horizontal separation from Black Hawk = 1000-ft (F-1)

Slant ranges = 1118-ft (F-1)

Slant angle = 26.5° (F-1)

F-2 Aircraft Geometry #2 (see Atch 1, Figure 2):

Altitude above Black Hawk = 300-ft

Horizontal separation from Black Hawk = 1500-ft

F-2 Aircraft Geometry #3 (see Atch 1, Figure 3)

Altitude above Black Hawk = 500-ft

Horizontal separation from Black Hawk = 2000-ft

F-15C Fighter Pilot Information

F-1 Pilot:

Corrected visual acuity = 20/20²

Wearing USAF-issued aviator prescription spectacles for myopic astigmatism

Wearing USAF-issued high-contrast "shooters" visor

F-2 Pilot:

Uncorrected visual acuity = 20/20

Wearing USAF-issued neutral gray (15%) sun visor

Other information

F-1 first realized that a moving dot target on his radar target designator (TD) box was an aircraft at about 7 nautical miles out. He could not visually see the aircraft because of his distance and the green terrain.

At about 5 nautical miles out, F-1 "picked up" the rotary blades of the target in his TD box and knew it was a helicopter. F-1 passes BH-L at about 500-ft higher altitude and approximately 1000-ft horizontal separation to his right. He is traveling approximately 450 knots and has about 5-10-s total visual identification time. He initially approaches BH-L by descending down with BH-L in the front of his canopy, and then he passes him from BH-L's left side and high, so that BH-L moved off to the right side of his canopy and F-1 viewed him from his right side.

F-1 said the color of the helicopters was green camouflage and that they were camouflaged well against the green background. He indicated that the helicopter was darker than the terrain.

BH-T was initially detected by F-1 as what he thought was a shadow of BH-L, but saw that it was another aircraft after he looked again.

Neither F-1 nor F-2 saw any identification markings on either helicopter. He said he did see sponsons on BH-L and that he saw ordinance on the sponsons, although he had only a partial view of the ordinance.

This was the initial US fighter aircraft fly-by of this Iraqi air zone. The air zone the Black Hawk helicopters were flying in at the time of the incident had not been previously briefed nor previously "sanitized" by a US aircraft fly-by (SOP).

F-1 pulled away from BH-L to avoid a perceived threat of a possible attack by a Hind helicopter.

BH-T aircraft was first detected by F-2 as a shadow, but he finally visually picked up both helicopters at low altitude in an echelon left formation. F-2 passed BH-T on the south side approximately 1500-2000-ft laterally and high, and saw a dark camouflaged body, sloping wings with external stores, and no fin flashes or markings. F-2 pulled up to avoid a flight path conflict with the lead helicopter and never got a good look at BH-L.

F-2 said BH-T's shadow was fairly defined. He said the helicopter had a dark camouflage body, a fairly blunt nose, and sponson that came down. He said he saw external stores on the sponsons. He said the helicopter had high engines and that the tail came back and then slanted (about 45°) coming back up. F-2 said he did not see any markings at all on the helicopter. F-2 said that neither visibility nor sun angle was a factor on his identifications.

Both F-1 and F-2 said that the two helicopters appeared to be Hind aircraft.

B. Visual Angle Determinations:

From the information given to us in Section III.A., we used standard physics and geometrical optics to determine the details of the flight geometries of F-1 and F-2, as well as to calculate the visual angles of the different helicopter features for F-1 and F-2. The following equations were used for these determinations:

$$\text{Slant range} = [(\text{altitude})^2 + (\text{horizontal separation})^2]^{1/2} \quad (1)$$

$$\text{Slant angle} = \arctan[(\text{altitude}) \div (\text{horizontal separation})] \quad (2)$$

$$\text{Visual angle } (\Theta) = \arctan[(\text{aircraft dimension}) \div (\text{slant range})] \quad (3)$$

See Atch 1 for the results of the aircraft geometry and visual angle calculations. Figure 1 schematically displays the aircraft geometry for F-1, and Figure 2 and Figure 3 show the two different aircraft geometries for F-2. The physical dimensions for these aircraft geometries are also calculated in each respective figure. Table 1 of Atch 1 gives the visual angles of the Black Hawk aircraft and its US and Red Cross flag marker features for the F-1 and F-2 aircraft slant ranges. In addition, Table 1 of Atch 1 also gives the distances for F-1 and F-2 at which features would subtend critical visual angles for target detection (i.e., I can tell something is there), target recognition (i.e., I can tell it is a certain shape), and target identification (i.e., I can tell it is a US or Red Cross flag). For the visual angles calculated in Table 1 of Atch 1, we assumed that the projected angle of the target is perpendicular to the line of sight. The actual projected visual angles are based on the slant viewing angle and the orientation of the sighted aircraft. The visual values given in Table 1 or Atch 1 are the largest possible values for the viewing distances and flight geometries.

Visual resolution for an individual with 20/20 visual acuity viewing **static, high-contrast** (≥ 0.90) targets (e.g., black letters on a white background) is generally held to be a visual angle of 1.0 arc-min. However, some reports indicate that for initial detection of negative-contrast targets (e.g., a Black Hawk that appears darker than the terrain), a minimum angular size of approximately 2.0 arc-min is required. For example, Morris, Temme, and Hamilton¹ found that for high-contrast spot targets under high illumination, a minimum angular size of just under 2.0 arc-min is required for threshold detection. Similarly, Hamilton and Monaco² found that a target angular size of 1.8 arc-min was required, on average, for operational "tally ho" detection by pilots when the target projected area and the expected slant range were taken into account. The VIDEM model³ of human target detection predicts that for a 13.6% contrast target, a minimum target angular subtense of 2.0 arc-min is required for threshold detection.

Based on this information, we conclude that target sizes of approximately 2 arc-min are required for initial target "tally ho" detection, and target angular sizes of 1 arc-min are required for detection of target features after the initial target "tally ho" detection has occurred. Larger target sizes are required for target recognition and target identification. The Johnson criteria⁴ indicates that the minimum target sizes for recognition must be approximately four times larger than those required for target detection, and approximately six times larger for target identification. The Johnson criteria was based static target viewing. Dynamic visual environments (such as the visual environment of this incident), visual clutter within the scene, workload, and other factors may increase the scaling factors for target recognition and target

¹Morris, A, Temme, LA, & Hamilton, P. 1988. What's wrong with the aviator's sun visor? *Report of the 28th Meeting of ASCC Working Party 61 Aerospace Medical Life Support Systems, volume IV*. Pensacola, FL: Naval Aerospace Medical Research Laboratory.

²Hamilton, PV & Monaco, WA. Air-to-air target detection by Navy pilots during ACM training. *Naval Aviation News*, 1987.

³Akerman, A & Hammil, H. 1986. *Camouflage Handbook* (AFWAL-TR-86-1028). Wright-Patterson AFB, Ohio. Avionics Laboratory.

⁴Johnson, J. Analysis of image forming systems. *Image Intensifier Symposium*, (pp. 249-273), Fort Belvoir, Virginia, 1958.

identification significantly over those used for the Johnson criteria.⁵ Using the Johnson criteria, and assuming the best case visual scenario (i.e., static, high-contrast targets), if a 1.0 arc-min target angular dimension is required for detection after the initial target "tally ho," a 4.0 arc-min target size will be required to recognize the target shape or target type (e.g., the target is a rectangle or the target is a flag), and a 6.0 arc-min target angular dimension will be required to identify the target (e.g., the target is a US flag). However, to identify a flag marker as a US flag, the observer must be able to detect the detail patterns of the star field and alternating red and white stripe. Therefore, for the US flag marker to be identifiable, these features must be larger than 1.0 arc-min at the different slant ranges. Similarly, the red cross within the white field of the Red Cross marker must also be resolvable (i.e., larger than 1.0 arc-min) for the Red Cross marker to be identifiable.

However, visual acuity is highly dependent on target contrast.⁶ The 1.0- and 4.0-arc-min angular sizes required for target detection and recognition, respectively, are for an observer with 20/20 visual acuity viewing relatively high-contrast targets. Medium- and low-contrast acuity is generally lower than high-contrast acuity. We recently determined the average acuity of six subjects, who met the visual requirements of a Flying Class II physical examination (per AFR 160-43), for targets of three different contrast levels.⁷ We found their average acuities to be 20/13 for 96% contrast targets, 20/18 for 11% contrast targets, and 20/40 for 4% contrast targets. All of our six subjects had corrected visual acuities of 20/20 or better. Therefore, using the 1.0- and 4.0-arc-min minimum target angular sizes to predict target detection and recognition thresholds, respectively, is only truly valid for those targets which have high contrast. This same point is also true for the 1.0 arc-min detection threshold criterion.

Using the spectral reflectances of the paints used for the Black Hawk helicopters (aircraft green #34031) and the US flag and Red Cross markers, we calculated the Weber contrasts⁸ of the different flag marker paint colors against the IR suppressive green Black Hawk paint, as well as the Michelson contrast⁹ of the red and white stripes within the US flag marker (Table B-1). These contrast calculations were made for the paints alone, as well as for the paints after transmission through the USAF-issued high-contrast "shooters" visor. For these contrast calculations, we used the average luminances of the different paints under the different viewing conditions (no visor and high-contrast "shooters" visor). The average luminances were calculated by first determining, as a function of wavelength, the luminance of the paint between 400-700 nm, and then calculating the mean luminance over these visible wavelengths.

As indicated in Table B-1, with the exception of the Weber contrast of -0.10 calculated for the blue paint against the Black Hawk IR suppressive green paint, all of the contrasts calculated for the different paint combinations are relatively high. Using

⁵Martin, Task, Woodruff, & Pinkus. (1976) Element density and percent active area design requirements for liquid crystal displays (AFAMRL-TR-75-235). Wright-Patterson AFB, Ohio: Armstrong Medical Research Laboratory.

⁶Wilson, HR. Psychophysical models of spatial vision and hyperacuity. In: D. Regan (Ed.): Vision and Visual Dysfunction: vol. 10, Spatial Vision. 1991: Boca Raton, Florida, CRC Press.

⁷Thomas, SR, McLin Jr, LN, Garcia, P, LaPage, C, & Apsey, DA. Optical characteristics and visual consequences of laser eye protection. *Optom & Vision Sci (Suppl)*, 1993:70, 98.

⁸Weber contrast = [(Target Luminance - Background Luminance) + Background Luminance]

⁹Michelson contrast = [(Maximum Luminance - Minimum Luminance) + (Maximum Luminance + Minimum Luminance)]

the 1.0 arc-min resolution criteria for targets of these contrasts levels is not grossly inappropriate. Therefore, using the 1.0-, 4.0-, and 6.0-arc-min criteria visual angles for predicting whether a US flag marker or a Red Cross marker on the Black Hawk helicopters were detectable, recognizable, and identifiable, respectively, are not inappropriate provided that the effects of other factors inherent to the incident that can reduce visual ability are also taken into account. The three criteria minimum visual angles we are using for our predictions were also determined based on an additional assumption of static target viewing, which was not the case for the F-1 and F-2 pilots during their mission. The dynamic components of the actual visual scene will also affect target detection, recognition, and identification. The ability to detect high-spatial frequency targets (i.e., fine spatial detail) generally declines as the temporal frequency of the target increases.¹⁰ In summary, all of our subsequent predictions about target visibility, which are based on the calculations in Table 1 of Atch 1, likely represent the best case visual scenario, since the dynamic aspects of the visual scene have not been taken into account.

Table B-1. Mean Luminances and Contrasts of Flag Marker Features

<u>Paint</u>	<u>No Visor Luminance</u>	<u>No Visor Contrast</u>	<u>Shooters Visor Luminance</u>	<u>Shooters Visor Contrast</u>
Blue	2142.8	-0.10	833.2	-0.65
Red	10242.2	3.29	7923.5	2.32
White	29295.2	11.28	12019.0	4.04

Michelson Contrast of Red and White Stripes:

No Visor = 0.48

Shooters Visor = 0.21

All luminance values given in cd/m^2

Given these criteria and their assumptions, the visual angle information in Table 1 of Atch 1 can be used to predict, for those targets having relatively high contrasts, whether F-1 and F-2 could detect, recognize, and identify the different marker features on the Black Hawk helicopters, at their calculated slant ranges. In addition, we can predict the range at which F-1 or F-2 would have had to have been from the Black Hawk helicopters for the different marker features to have subtended the minimum criteria sizes for target detection, recognition, and identification (Table 1, Atch 1). Calculations for a Red Cross marker on a Black Hawk helicopter were also made, at request, for comparisons with the calculations for the US flag marker, even though Red Cross markers were not on the actual Black Hawk helicopters in the incident.

In Table 1 of Atch 1, all of the visual angles that are smaller than 1.0 arc-min are likely to not be discernible to the F-15C pilots at their different respective distances. For F-1 at the 1118 slant range, the outer dimensions of the US flag and

¹⁰Wilson, HR. Psychophysical models of spatial vision and hyperacuity. In: D. Regan (Ed.): Vision and Visual Dysfunction: vol. 10, Spatial Vision. 1991: Boca Raton, Florida, CRC Press.

[REDACTED]

the Red Cross markers are greater than the 4 arc-min value required for target recognition. Therefore, we predict that if F-1 was able to acquire the US flag and Red Cross markers, he would have been able to recognize their outer border shapes. To identify the US flag marker, F-1 would have to be able to detect either the star field and/or the width of the alternating red and white stripes within the flag. Therefore, the angular subtense of the stars and/or the individual red and white stripe widths would have to be 1.0 arc-min or larger. Table 1 of Atch 1 indicates that the angular dimensions calculated for these features at the 1118-ft slant range were well below 1.0 arc-min detection threshold value, and, therefore, were not detectable. Because F-2 was further away from the US flag marker than F-1, we would also predict that he could not identify the US flag marker. In fact, we calculated that an observer would have to be 501.3-ft from the US flag marker for the width of the stripes to subtend 1 arc-min, and, thus, be detectable. For both F-2 flight geometries, both sides of the US flag marker were determined to be above target detection threshold, and at least one side was large enough to be above the 4.0 arc-min target recognition threshold. These calculations assume that the view of the US flag is perpendicular to the observer. The calculated distances to achieve different target visual angles will increase depending on the look-down angle between the observer and the flag target.

The outer boundary of the Red Cross marker was square shaped. The sides of the square was the same size as the shorter side of the US flag marker. We calculated that the visual angles of the sides of the outer boundary were below the 4-arc-min size required for target recognition by F-1 and F-2. For F-2 in flight geometry #3, this size was below target recognition threshold. We calculated that the white field portions of the Red Cross marker would be large enough for target identification target recognition at a range of 1575.6 ft. We also calculated that the observer would have to be no further than 1718.9 ft from the target for the width of the red bar within the white field to be above detection threshold (1 arc-min). Thus, F-1 and F-2 would not be able to identify the Red Cross marker beyond a range of 1718.9 ft. In addition, we calculated that at 859.4 ft from the Red Cross marker, the width of the red bar within the white field would subtend 2 arc-min. The arms of the cross would subtend 6.0 arc-min, so the cross would likely be identifiable.

Calculations were also done to predict the amount of time the US flag and Red Cross markers' horizontal dimensions would subtend 4 arc-min criteria sizes required for target recognition (Table B-2). For these calculations, we assumed the fighter aircraft was approaching the Black Hawk helicopter from behind at a speed of 450 knots. The Black Hawk was assumed to be traveling in the same direction as the fighter at a speed of 130 knots. The flight paths of the fighter and the Black Hawk were assumed to be parallel. The times in Table B-2 are given for the F-1 and F-2 slant ranges when the fighter is abeam to the Black Hawk. The flag dimensions were adjusted based on the viewing geometry. The maximum horizontal size (max-hor-size) is the size of the horizontal dimensions of the flag, in arc-min, when the two aircraft are abeam. The vertical dimensions (vert-dim) of the flag that correspond to each max-hor-size are also given in arc-min in Table B-2. The vert-dim sizes were also adjusted for the aircraft viewing geometry. The times associated with the flag dimensions represent the amount of time that these dimensions subtended the visual angles identified in Table B-2. From these data, one can appreciate the amount of time in which F-1 and F-2 were capable of potentially recognizing the outer boundary of the flag markers given their flight geometries and airspeed.

Table B-2. Estimated Time Specific Flag Marker Visual Angles Were Observed

<u>Slant range</u>	<u>Max-hor-size</u>	<u>4 Arc-min</u>	<u>6 Arc-min</u>	<u>Vert-dim</u>
1118 ft	9.2 arc-min	5 sec	2.5 sec	> 3 arc-min
1529 ft	6.7 arc-min	4 sec	2 sec	> 3 arc-min
2061 ft	5.0 arc-min	3.5 sec	0 sec	> 2.7 arc-min

The times calculated above will be reduced if the criteria visual angle sizes are increased.

C. Apparent Contrast Determination.

One of the most important factors that influence target detection and identification is the target apparent contrast.¹¹ In real-world environments, the apparent contrast of the target against the background, which accounts for the loss in target and background contrast from atmospheric scatter, must be determined prior to predicting whether a target can be detected or identified. To determine the apparent contrast (C_o) of a low-altitude aircraft being viewed against a terrain background from above (by a low-altitude aircraft), the following equation should be used:¹²

$$C_o = C_1 \{ 1 - K[1 - e^{3.912 R/V}] \}^{-1} \quad (4)$$

Where: C_1 = Target-background Weber contrast
 K = Sky-ground luminance ratio
 R = Slant range
 V = Visibility along the slant range

This apparent contrast equation is only valid in this viewing scenario when the slant range and the visibility along the slant range are known.

Using Equation 4, we calculated the range of probable Black Hawk apparent contrasts for the different aircraft slant ranges specified for F-1 and F-2 (Atch 1). The target (i.e., Black Hawk) and background (i.e., terrain) luminances were determined using the following equations:

$$\text{Black Hawk luminance} = r_{\text{paint}} \times (E_{\text{sun}} + \pi) \quad (5)$$

Where: r_{paint} = Reflectance of the Black Hawk paint (7.5%)
 E_{sun} = Illuminance of the sun¹³

$$\text{Terrain luminance} = r_{\text{terrain}} \times (E_{\text{sun}} + \pi) \quad (6)$$

Where: r_{terrain} = Reflectance of the terrain (7.6% - 10%)
 E_{sun} = Illuminance of the sun

¹¹ Akerman, A & Hammil, H. 1986. *Camouflage Handbook* (AFWAL-TR-86-1028). Wright-Patterson AFB, Ohio: Avionics Laboratory.

¹² Akerman, A & Hammil, H. 1986. *Camouflage Handbook* (AFWAL-TR-86-1028). Wright-Patterson AFB, Ohio: Avionics Laboratory.

¹³ This value was calculated to be $3.18 \times 10^4 \text{ cd/m}^2$

The reflectance of the Black Hawk paint was given to us by the Accident Board. The reflectance values used for the terrain were selected because they represented real-world reflectances measured for green terrains,¹⁴ which would also give negative apparent contrast values. Testimony from both F-1 and F-2 indicated that the helicopters appeared to be darker than the green terrain, even though they were well camouflaged. These statements indicate that the Black Hawk helicopters had a negative apparent contrast against the northern Iraqi mountainous terrain over which they were flying. The sun illuminance value (in lux) was also taken from the *Camouflage Handbook*,¹³ to be a good estimate of sun illuminance during a clear April day at 1130 hours.

The range of Black Hawk apparent contrasts (Table C-1) varied significantly for the different aircraft slant ranges. The exact apparent contrast of the Black Hawk cannot be accurately determined unless the actual reflectance of actual terrain over which the Black Hawk helicopters were flying is known. In general, the greater the slant range of the fighter aircraft from the Black Hawk, the lower the possible Black Hawk apparent contrasts. However, there is considerable overlap in the ranges of possible Black Hawk apparent contrasts for the three different aircraft slant ranges.

Table C-1. Range of Possible Black Hawk Apparent Contrasts as a Function of Slant Range

<u>Slant range</u>	<u>Terrain Reflectance</u>				
	<u>7.6%</u>	<u>8.0%</u>	<u>8.5%</u>	<u>9.0%</u>	<u>10%</u>
1118 ft	-0.009	-0.045	-0.085	-0.121	-0.181
1529.7 ft	-0.009	-0.041	-0.077	-0.109	-0.164
2061.6 ft	-0.008	-0.036	-0.068	-0.097	-0.145

Contrast values can be transformed into percent contrast values by multiplying the values by 100.

The VIDEM model¹³ is one method by which the detectability of a target can be predicted from its visual angle and apparent contrasts. From the VIDEM model, targets subtending the visual angles calculated for the Black Hawk aircraft and its marker features would have to have apparent contrasts of at least ± 0.034 to be detected. In general, the smaller the visual angle subtended by the target, the greater the apparent contrast threshold. For target identification, either the visual angle of the target or the apparent contrast of the target against the background would have to be increased above the respective threshold for target detection. As previously mentioned, the visual angle of the target would have to be increased by a factor of at least six for target identification.¹⁵ The VIDEM model assumes that the target is viewed against a

¹⁴Akerman, A & Hammil, H. 1986. *Camouflage Handbook* (AFWAL-TR-86-1028). Wright-Patterson AFB, Ohio: Avionics Laboratory.

¹⁵ Johnson, J. Analysis of image forming systems. *Image Intensifier Symposium*, (pp. 249-273), Fort Belvoir, Virginia, 1958.

homogeneous background (e.g., clear sky), as opposed to a structurally rich terrain background (mountain valley with sparse foliage). Spatial masking by spatial frequencies contained within the terrain (i.e., clutter) could potentially increase the target detection and identification thresholds above that predicted by the VIDEM model¹⁶ or the Johnson criteria.¹⁴

D. Effects of Visor and Canopy Materials.

With the exception of magnification optics, optical materials between the observer's eye and the target generally tend to reduce target and background luminance to some extent. If the optical material absorbs visible wavelengths of light by approximately the same amount, such as the USAF-issued (15%) sun visor, the optical material would not be expected to affect the apparent contrast of the target, provided that the visor did not contain significant amounts of haze or scratches. Visor materials containing significant amounts of haze or scratches could reduce the contrast of a target. The military standard for aircrew visor haze is 2% or less. In case of the USAF-issued sun visor, the target and background luminances would be reduced by approximately 85%.

If the optical material selectively absorbs visible wavelengths of light, both the luminance and the apparent contrast of the target could be affected. The apparent contrast of the target against the background would be affected if the target and/or the background reflected wavelengths of visible light that were absorbed by different amounts by the selective absorption optical material. In addition, selective absorption filters (e.g., Blue-blockers sunglasses) can also alter the color appearance of objects.^{12,17,18}

The USAF-issued high-contrast "shooters" visor selectively absorbs visible wavelengths of light between 400 - 520 nanometers (nm), and, therefore, could affect both the luminance and color contrasts, as well as the color appearance of targets and backgrounds that reflect short visible wavelengths of light. Blue target detection would be most affected by high-contrast visor use. For the US flag markers on the Black Hawk helicopter, the blue portion of the flag was displayed against the IR suppressive green aircraft paint background. As shown in Table B-1, the effect of the high-contrast visor was to increase the negative contrast of the blue paint against the green paint background from -0.10 to -0.65. Although the negative contrast was increased, the appearance of the blue portion of the flag marker would likely be a darker black square on a black background. It is likely that this portion of the flag would have been poorly visible, if visible at all, had it been acquired by F-1, who was wearing the high-contrast "shooters" visor. In addition, Table B-1 shows that the Michelson contrast of the red and white stripes in the US flag marker is reduced from 48% to 21% after transmission through the high-contrast visor. This reduction in contrast could affect target detection at larger slant ranges.

The effects of yellow lenses, such as the high-contrast visor, has been evaluated in the field and in the laboratory. The results of these studies, in

¹⁶ Wilson, HR. Psychophysical models of spatial vision and hyperacuity. In: D. Regan (Ed.): Vision and Visual Dysfunction: vol. 10, Spatial Vision. 1991: Boca Raton, Florida, CRC Press.

¹⁷ Kuyk, TK & Thomas, SR. Effect of short wavelength absorbing filters on Farnsworth-Munsell 100-Hue test and hue identification task performance. *Optom & Vis Sci*, 1990:67, 522-531.

¹⁸ Hovis, JK, Lovasik, JV, Cullen, AP, & Kothe, AC. Physical characteristics and perceptual effects of "blue-blocking" lenses. *Optom & Vis Sci*, 1989:66, 682-689.

terms of the visual benefits of the yellow lenses, conflict with subjective reports. Many pilots think the high-contrast visor reduces haze and improves contrast, and is of benefit during air-to-air missions.¹⁹ However, color alterations induced by the high-contrast visor have been cited as a decrement for its use during air-to-ground missions.¹⁹ Laboratory and field investigations fail to validate these subjective reports of the benefits of yellow lenses for target acquisition, but they do report color vision abnormalities when yellow lenses are worn. For example, Kislin²⁰ found no calculable advantage in detecting defoliated native tree leaves with colored lenses. A field study examining the effects of yellow lenses of the ability of F-4 pilots (flying at high speed and low-altitude) at identifying "real-world" targets found no difference in performance when the yellow lenses were used.²¹ A more thorough review of the consequences of wearing yellow filters on visual performance can be found elsewhere.²²

The F-15 canopy also absorbs some visible light. The photopic luminous transmittance of F-15 canopy is approximately 80%. Thus, the canopy, as well as the visors, reduce the target luminance. In addition, haze in the aircraft canopy, as well as its general physical conditions (i.e., scratchiness) can also affect target luminance and apparent contrast. Haze in F-111 and F-16 aircraft polycarbonate canopy material have been found to reduce target contrast by as much 76%,²³ depending on the sun elevation angle. Reductions of between 0 - 76% would lower many of the possible Black Hawk apparent contrast values given in Table C-1 to below target detection threshold (as predicted by the VIDEM model).

Many of the effects of visors and canopy materials on visual performance can be summarized by the following quote from a section from the *Camouflage Handbook* (paragraph beginning on the bottom of page 1.1-23):

"Optical aids, such as binoculars and telescopes, may either aid or handicap an observer. These aids often are detrimental to search, because they restrict the area that can be searched at one glance. However, they may be useful for detection under a limited range of adverse viewing conditions. Also, magnifying optical aids may be useful for identification, once a target has been located. Other optical materials interposed between the observer and the aircraft will, usually, handicap his capacity to detect or identify an aircraft, either due to brightness loss and/or color shift caused by the transmission characteristics of the material or due to distortion caused by the optical quality of the material. Special colored filters--for example, yellow filters--for "breaking" camouflage schemes have been found not to improve detection in the field, probably due to these factors."

¹⁹Minutes of the Visual Enhancement and Eye Protection (VEEP) Integrated Product Team Meeting. USAF Armstrong Laboratory, Brooks AFB, Texas, 9-10 April 1994.

²⁰Kislin, B. (1968). The use of yellow lenses in Air Force operations (SAM-TR-68-93). Brooks AFB, Texas: School of Aerospace Medicine.

²¹Provines, W, Rahe, A, Block, M, Pena, T, & Tredici, T. (1982). Yellow ophthalmic filters in the visual acquisition of aircraft (SAM-TR-83-46). Brooks AFB, Texas, School of Aerospace Medicine.

²²Minutes of the Visual Enhancement and Eye Protection (VEEP) Integrated Product Team Meeting. USAF Armstrong Laboratory, Brooks AFB, Texas, 9-10 April 1994.

²³Task, HL & Genco, LV. (1985). The measurement of aircraft windscreen haze and its effect on visual performance (AFAMRL-TR-85-016). Ohio: Wright-Patterson AFB, Air Force Aerospace Medical Research Laboratory.

In addition, reflections from visor and/or canopy material could also serve as a source of veiling glare, which would also lower target apparent contrast and affect detection or identification threshold.

Finally, optical distortions in aircrew visor or aircraft canopy materials can also reduce target detection and identification. The military standard for aircrew visor materials is given in Atch 2. Whether the optical distortion within an aircrew visor meets military standards is based on a purely subjective evaluation of whether the visor optical distortion grating patterns are more similar to the "acceptable" or the "unacceptable" military standard patterns. Optical distortion of visor or canopy material is not given as an objective number value, and to our knowledge, the effects of varying amounts of optical distortion in these materials on visual performance has not been systematically studied. A more objective measure of aircrew visor and canopy optical distortion, which is correlated to visual performance capabilities, is needed for the military standard.

E. Other Factors that Influence Target Detection and Identification.

There are several other factors besides visual angle and apparent contrast that can influence the target detection and identification capabilities of an observer. The impact of several of these factors are discussed in an excerpt of the *Camouflage Handbook*.²⁴ For example, the 450-knot ground speed of the fighter aircraft will add a temporal component to the visual scene that will influence target detection. As previously mentioned, adding a temporal component to the target can reduce the detection and identification thresholds of high-spatial frequency (i.e., small visual angle) targets.

For target detection, recognition, and identification, the fovea of the retina must be used for optimal visual performance. The more eccentric the portion of the visual field of which the target is viewed, the lower the visual resolution ability of the observer. Visual acuities, such as 20/20 visual acuity, are typically only representative of foveal vision, which corresponds to the center of the visual field. Visual acuity drops dramatically as fixation shifts from the fovea. If F-1 and F-2 had to rely on peripheral viewing for their recognition or identification of the helicopters or their marker features, their visual performance capabilities would be lower than that expected when foveal viewing was used. The magnitude of these potential effects is impossible to predict without knowing which portion of their visual field was used and for which types of visual tasks.

In addition, the features of a friend or foe aircraft of which the pilots were trained to make identifications will also influence how the targets are identified. To accurately predict the range at which a Black Hawk aircraft can be identified, one would need to determine the visual angles of these identification features and the contrasts at which they remain above identification threshold. The probability of making erroneous target identifications, in general, increases if the apparent contrast is low, the projected visual angle is obtuse, and/or the target presentation time is short.

F-2 indicated that he first detected BH-T from a fairly detailed shadow of the aircraft on the ground, and from that shadow he predicted BH-T to be flying lower than 500-ft AGL. F-1 estimated the altitude of BH-L and BH-T to be

²⁴Akerman, A & Hammil, H. 1986. *Camouflage Handbook* (AFWAL-TR-86-1028). Wright-Patterson AFB, Ohio: Avionics Laboratory.

[REDACTED]

no greater than 300-ft AGL. For the calculations in Atch 1, we estimated the altitude of the Black Hawk helicopters to be approximately 200-ft AGL. The *Camouflage Handbook*¹³ lists minimum altitudes for avoidance of shadows on the ground by a "typical" helicopter. For a sun elevation of 70°, the minimum altitude is 1300 ft. The shadows cast from an altitude of 200 ft may have helped the F-15C pilots in detecting the Black Hawk helicopters, but it is unlikely that the shadow patterns could have aided their ability to correctly identify the helicopters as being Black Hawks.

The expectation set of the F-15C pilots at the time of the target identification could also influence their visual perceptions. For example, if the Black Hawk helicopters were flying in an area where they were not expected to be, the F-15C pilots' visual perception of them may have been biased by their expectations of the types of aircraft they would likely encounter in that area. The information briefed to the F-15C pilots prior to their mission, as well as their experiences on previous missions, could also influence their visual perceptions. Finally, the workload of the F-15C pilots at the time of their initial detection, recognition, and identification of the Black Hawk helicopters could also influence their visual abilities. If the F-15C pilots were busy performing aerial maneuvers, their visual attention could have been reduced, thereby potentially lowering their overall visual abilities.

IV. DETERMINATION:

A. Visual Detection and Identification of Black Hawk Aircraft and US Flag Markers:

1. **THESE PREDICTIONS ARE BASED ON THE CALCULATIONS IN ATCH 1, AND THEY ARE ONLY VALID FOR THE CONDITIONS AND ASSUMPTIONS ON WHICH THE CALCULATIONS ARE BASED (SPECIFIED IN ATCH 1 AND SECTION III.B).** The predictions are based on the assumptions that the helicopters and their marker features must subtend critical visual angle sizes for target detection (1.0 arc-min), recognition (4 arc-min), and identification (6.0 arc-min or 1 arc-min for identifying features within the target) to occur. The critical target angular sizes were based on visual resolution abilities of an individual with 20/20 vision viewing static, high-contrast targets. The dynamics of the actual visual scene, visual clutter within the actual scene, workload, and other factors can result in significantly larger critical visual angle sizes (and therefore smaller viewing ranges) to be required for target detection, recognition, and/or identification. Flight testing is required to obtain better predictions of target detection and identification under conditions similar to those present during the actual incident.

2. US Flag Marker

a. For F-1 at a 1118-ft slant range, the angular subtense of the outer boundaries of the US flag marker were calculated to be above our detection and recognition threshold visual angle sizes. To identify the flag marker as a US flag, we predict that either the star field of the flag and/or the stripes of the flag must be identifiable. Therefore, the angular subtense of either the star field on the flag and/or of the width of the individual red and white stripes in the flag must exceed the 1.0 arc-min threshold for target detection. We calculated that the angular subtense of the stars and the stripe widths were 0.29 arc-min and 0.45 arc-min, respectively, which indicates these features were below detection threshold (1 arc-min). From these calculations and their associated assumptions (Atch 1), we predict that had F-1 acquired the US flag marker on the helicopters, he would have been able to recognize it as being rectangular in shape, but he would have very likely not been able to identify it as being a US flag.

b. F-1's use of the high-contrast visor could have affected his visual abilities by reducing the luminance and contrast of the scene and altering its color appearance.

c. For F-2 at the 1529.7-ft slant range (geometry #2), we calculated the angular subtense of the boundaries of the US flag marker to be greater than that required for target detection and target recognition threshold. The angular sizes of the stars and stripe widths within the flag were far below the 1.0 arc-min threshold required for their resolution. Therefore, we predict from these calculations and their assumptions that if F-2 had acquired the US flag marker on the helicopters at the 1529.7-ft slant range, he would have been able to recognize the shape as being rectangular, but it is doubtful he would have been able to resolve enough detail within the flag to identify it as being a US flag marker.

d. For F-2 at the 2061.6-ft slant range, the angular subtense calculated for the boundaries of the US flag marker were greater than that

[REDACTED]

required for target detection. Only the angular subtense of the longer portion of the flag boundary was large enough to exceed the 4.0 arc-min size required for target recognition. The stars and stripe width sizes calculated at this slant range were far below detection threshold. From these calculations and their associated assumptions, we predict that if F-2 had acquired the US flag marker on the helicopter at the 2061.6-ft slant range, it is likely that he could have detected something on the helicopter, but it is questionable if he could have recognized its shape or identified it as a US flag.

e. Because the USAF sun visor reduces target luminance by approximately 85%, use of this visor by F-2 could have affected his target detection, recognition, and identification abilities. However, unlike the USAF high-contrast visor, we do not predict that the sun visor would have altered the color appearance of the US flag marker.

f. It is questionable whether the colors of the US flag marker could have aided F-1 or F-2 in their identification at the slant ranges on which the calculations were based. For very small visual targets (i.e., $< 0.5^\circ$), detection is mediated by a wavelength additive mechanism which has similar spectral sensitivity as the achromatic luminance mechanism.²⁵ It is likely that the US flag marker would have appeared desaturated at these slant ranges, or that the colors within the flag marker would have been poorly distinguishable.

3. Red Cross Marker.

a. The sides of a Red Cross marker were the same size as the shorter side of the US flag marker. Therefore, from the angular subtense calculations discussed in section IV.A.1., we predict that the F-1 could have detected and recognized the shape of a Red Cross flag marker if he had acquired the target during his visual search. F-2 could have also recognized the shape of a Red Cross flag marker at the 1529.7-ft slant range, but not at the 2061.6-ft slant range. At the longer slant range, we predict that F-2 would have only been able to detect the presence of an unresolvable marker on the helicopter.

b. In addition, we predicted that F-1 would have been able to recognize the white field sections of a Red Cross marker because they would have been larger than the 4-arc-min size at the 1118-ft slant range. F-2 could have also recognized the white field in a Red Cross marker at the 1529.7-ft slant range, but not at the 2061.6-ft slant range.

c. The width of a red cross on a Red Cross flag marker was calculated to be large enough to exceed detection threshold (i.e., 1 arc-min) at approximately 1718.9 ft. This indicates that F-1 could have detected the width of a red cross had he acquired the target. F-2 could have also detected this feature at the 1529.7-ft slant range had it been acquired. In addition, we predict that the width of a red cross bars would have subtended 2 arc-min at a range of 859.4 ft. F-1 and F-2 could have probably identified a red cross at 859.4 ft.

²⁵Thomas, SR. (1989). Spatiotemporal properties of peripheral color mechanisms. PhD Dissertation. University of Alabama at Birmingham, Birmingham, Alabama.

3. Black Hawk Outline

a. The angular subtense calculated for the area of the Black Hawk helicopters at the three different slant ranges exceeded the size required for target identification. However, unlike the flag markers, our estimate of the apparent contrast of the Black Hawk aircraft can not be accurately predicted from the information provided. According to the VIDEM model, an apparent contrast of ± 0.034 is required for target detection. Either larger angular sizes or larger apparent contrasts will be required to recognize and correctly identify the helicopters. The range of possible Black Hawk contrasts extended from -0.009 to -0.145% for the different slant ranges. The ± 0.034 apparent contrast minimum value falls within the range of possible Black Hawk apparent contrasts for visual detection at all three aircraft slant ranges. Without knowing the actual reflectance of the terrain, we cannot accurately calculate the apparent contrast of the Black Hawk helicopters, and, therefore, we cannot predict whether sufficient contrast was present for target recognition and identification. In addition, we do not know what features F-1 and F-2 were trained to use to identify the helicopters as being Black Hawks, although from their testimonies, they did believe that they saw several features that they were trained to use to identify Hind helicopters. Because a variety of other factors could influence the perception of the helicopters, we cannot make any predictions about the visibility of the Black Hawk aircraft other than that they were above detection threshold and that their color was correctly identified as being green by F-1.

B. Effects of USAF-Issued Visor Use

1. The use of the USAF sun and high-contrast visors could potentially reduce the target detection and identification abilities of the USAF F-15C pilots. The actual impact of the use of these visors is dependent on the actual apparent contrast of the Black Hawk helicopters. Empirical field tests are the best method to determine the magnitude of these effects.

2. The effects of the high-contrast visor on visibility are likely to be greater than those of the sun visor, because the high-contrast visor has a greater potential to reduce the apparent luminance and color contrast of the Black Hawk helicopters and their marker features, as well as alter the color appearance of the visual scene. In addition, the ability to detect and/or identify the blue portion of the US flag marker on the Black Hawk helicopters could have been adversely affected by the use of the high-contrast visor. Empirical field testing is the best method of evaluating the magnitude of these potential effects.

C. Other Factors.

1. The psychological state of the F-15C pilots could have influenced their visual perception of the Black Hawk helicopters. The information on which they were briefed prior to the mission, their previous experience flying over this area, and their expectations of what aircraft they would encounter in this area all could have influenced their perceptions.

2. If F-1 and F-2 had to rely on peripheral vision to assist them in recognizing and/or identifying the helicopters, their visual abilities would have been significantly less than those described for foveal (i.e., center of the visual field) vision. For optimal target detection, recognition, and identification

performance, foveal vision must be used. The magnitude of the reduction in vision resulting from eccentric viewing cannot be predicted without knowing which portion of the visual field was used and for which types of visual tasks.

3. The visual resolution values used for these predictions assume relatively high-contrast, static targets are viewed. The dynamic component of the actual visual scene could definitely affect the visual abilities of F-1 and F-2. For small, high spatial frequency targets, the effect of adding the temporal component to the visual scene could have reduced the F-15C pilots' visual abilities. In addition, spatial masking by the spatial frequency components (clutter) within the terrain could also raise the required thresholds for target recognition and identification.

4. The features which the F-15C pilots were trained to use to identify a Black Hawk helicopter and a Hind helicopter could have influenced their visual identifications. In addition, the actual projected angle shape of the helicopter and helicopter marker images could have influenced their identifications.



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ATTACHMENT 1

Visual Angle and Aircraft Geometry Calculations



Geometry 1 (See diagram in Attachment 1, Figure 1)

Note that the angular subtense values are the largest possible for the viewing distance given. Projected angle, based on slant viewing angle and orientation of sighted aircraft, will be smaller than the given values which assume the sighted aircraft is perpendicular to the line of sight.

Distances and angles

500 ft above BH (700 ft AGL)
 1000 ft horizontal to BH
 slant range = 1118.03 ft or 340.78 meters
 slant angle = 26.57 degrees

flag size			angular subtense
short side =	1 ft, 10 in	0.56 m	5.63 arc-min
long side =	3 ft	0.91 m	9.22 arc-min
area=	5.50	0.51 m ²	51.91 arc-min ²
stripes=	1.75 in	0.04 m	0.45 arc-min
stars=	1.125 in	0.03 m	0.29 arc-min

Geometry 2 (See diagram in Attachment 1, Figure 2)

Distances and angles

300 ft above BH
 1500 ft horizontal to BH
 slant range = 1529.71 ft or 466.25 meters
 slant angle = 11.31 degrees

flag size	angular subtense
short side =	4.11 arc-min
long side =	6.74 arc-min
area=	3.76 arc-min ²
stripes=	0.33 arc-min
stars=	0.21 arc-min

Sizes of flag are factor of 0.73 smaller than F-1.

Geometry 3 (See diagram in Attachment 1, Figure 3)

Distances and angles

500 ft above BH
 2000 ft horizontal to BH
 slant range = 2061.55 ft or 628.36 meters
 slant angle = 14.04 degrees

flag size	angular subtense
short side =	3.05 arc-min
long side =	5.00 arc-min
area=	2.79 arc-min ²
stripes=	0.24 arc-min
stars=	0.16 arc-min

Sizes of flag are factor of 0.54 smaller than F-1.

Dimensions of the Black Hawk

Range			1118 ft	1529.7 ft	2061 ft
Black Hawk dimensions	feet	meters	arc-min	arc-min	arc-min
Fuselage length	50 ft 7.5 in	15.43	155.56	113.73	84.40
Fuselage width with ESSS	20 ft 2 in	6.15	62.00	45.32	33.63
Fuselage height	9 ft 5 in	2.87	28.95	21.16	15.70
Estimated area					
side view	290.00 ft ²	alpha ² =	37598.40 arc-min ²	20084.61 arc-min ²	1027.91 arc-min ²
plan view	290.00 ft ²	alpha ² =	37598.40 arc-min ²	20084.61 arc-min ²	1027.91 arc-min ²
front view	100.00 ft ²	alpha ² =	12964.96 arc-min ²	6925.73 arc-min ²	354.45 arc-min ²
	Contrast threshold =	side view	0.034	0.034	0.034
		plan view	0.034	0.034	0.034
		front view	0.034	0.034	0.035

Many laboratory experiments are based on detection of circular disks.
 Alpha is the diameter of a disk of equivalent area to that actually projected by the aircraft.
 Note: Alpha = 6875.5/slant range*(projected area/Pi)^{0.5}
 Contrast threshold = 0.0334 + 0.409/alpha²

U.S. flag

Distance for horizontal dimension of U.S. flag to subtend:

2.00 min-arc	5158.62 ft	Stripe width	0.10 arc-min
4.00 min-arc	2578.31 ft		0.19 arc-min
5.00 min-arc	2062.65 ft		0.24 arc-min
6.00 min-arc	1718.87 ft		0.29 arc-min

Distance for stripe width to subtend:

0.50 min-arc	1002.68	This assumes perpendicular viewing of the flag. The distance will be increased, depending on the look down angle.	
1.00 min-arc	501.34		

Red Cross

dimensions

bar width	6.00 in
bar length	18.00 in
white field	22.00 in square

Distance for the white field to subtend

2.00 arc-min	3151.27 ft
4.00 arc-min	1575.63 ft
5.00 arc-min	1260.51 ft
6.00 arc-min	1050.42 ft

Distance for bar width to subtend

1.00 arc-min	1718.87 ft
2.00 arc-min	859.44 ft

Below are schematics, based on the information you gave us, for geometries of the F-15 fighter aircraft relative to the Black Hawks. The Black Hawks were 200 feet AGL. Figure 1 shows the geometry when fighter-1 (F-1) was abeam with the lead Black Hawk (BH-L). The Black Hawk, flying at approximately 130 knots, is facing the same direction as F-1, who was flying at 450 knots. Figures 2 and 3 are for the two additional fighter geometries we received for F-2 relative to the trail Black Hawk (BH-T). F-2 and BH-T are abeam, and traveling in the same direction.

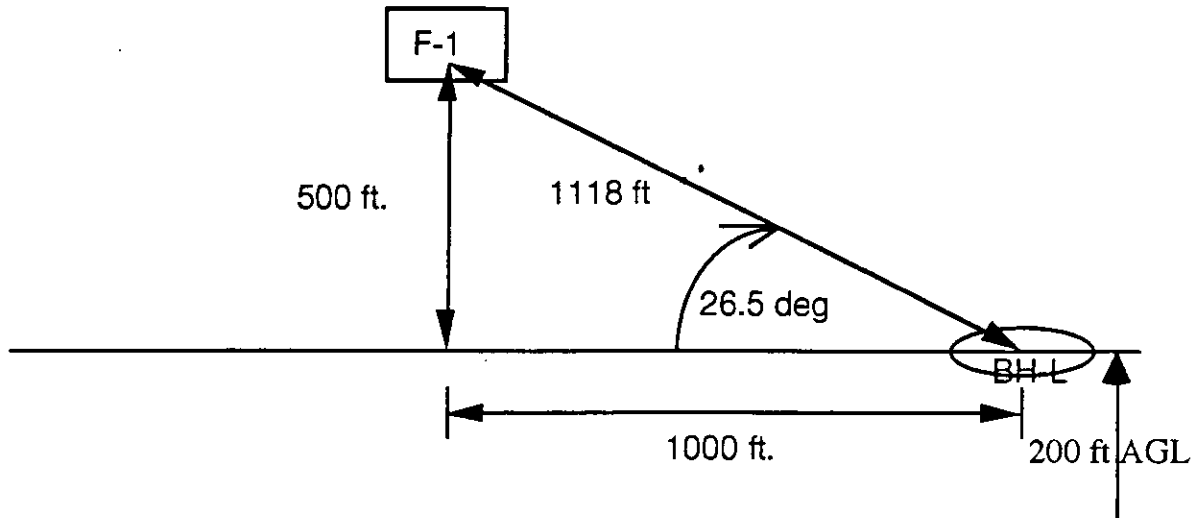


Figure 1. F-1 is at a slant range of 1118 feet from BH-L and the look down angle is 26.5 degrees.

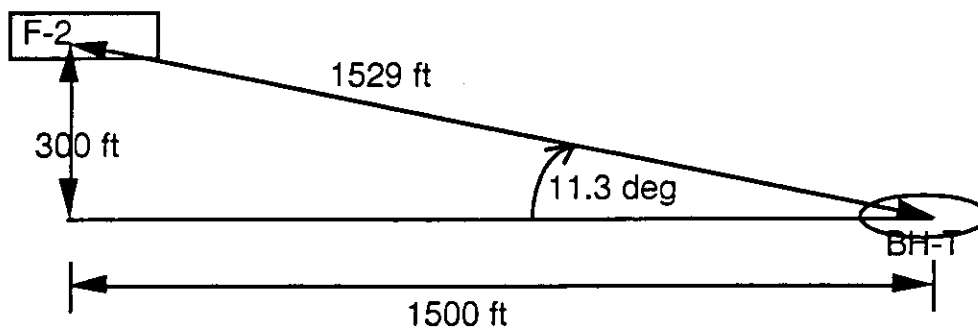


Figure 2. F-2 is at a slant range of 1529 feet from BH-T, and the look down angle is 11.3 degrees.

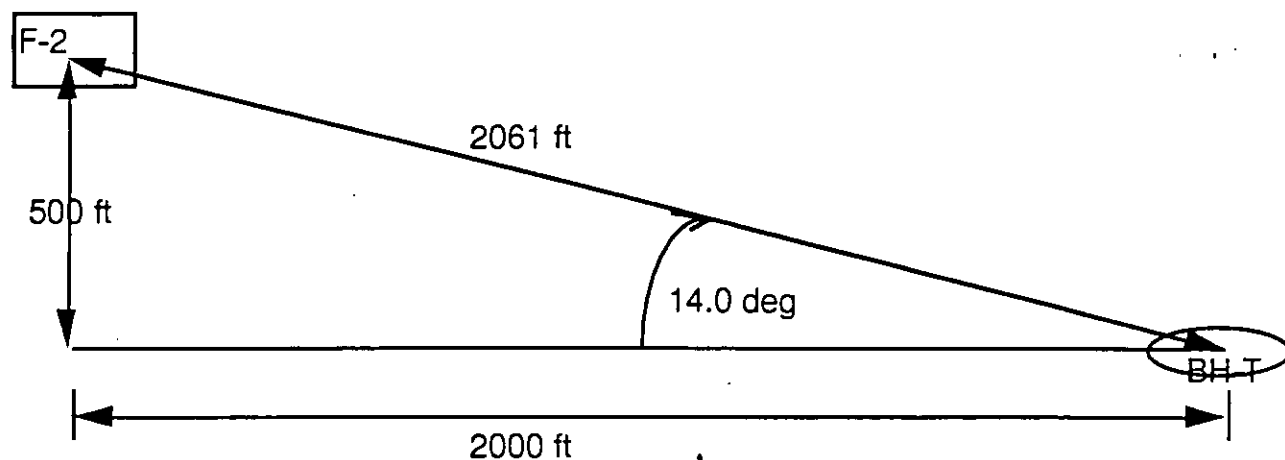


Figure 3. F-2 is at a slant range of 2061 feet from BH-T, and the look down angle is 14.0 degrees.

Dimensions of the U.S. flags.

From the dimensions you gave us for the flags on the door of BH (3 ft x 1 ft, 10 in), we calculate the maximum dimension of the flag to be 5.62 arc-min x 9.22 arc-min when viewed from F-1 in Figure 1. The stripes on the flag would have a width of 0.45 arc-min, based on a size of 1.75 inches. The stars on the flag would have a size of 0.29 arc-min based on a size of 1.125 inches. This is small enough that the stripes and stars of the flag would probably not be visible, and the flags would most likely be below identification threshold. Compare this to the 1 arc-min detail of the critical features of a 20/20 Snellen acuity letter. These dimensions would be significantly smaller for different angular views of the aircraft. If the helicopter was flying straight and level, looking down from F-1 at a slant angle of 26.5 degrees would reduce the vertical dimension of the door flag by the cosine of 26.5 degrees to a size of 5.03 arc-min. The curvature of the flag on the fuel tank might further reduce the visible vertical dimension of the flag. The overall dimension of a 20/20 letter is 5 arc-min. If the Black Hawk was approached from behind, it is highly possible that the flags were below threshold for identification and detection. The dimensions of the flag and angular sizes at different distances are also listed in Table 1.

In Figure 2 the horizontal dimensions of the flag would be reduced by a factor of 0.73 for the 1529.7 ft slant range compared to the dimensions of the BH-L viewed from F-1. Stripes would have a maximum width of 0.33 arc-min and the stars would have a maximum dimension of 0.21 arc-min.

For a slant range of 2061.6 ft, Figure 3 shows the dimensions of the flag would be reduced by a factor of 0.54 compared to the dimensions in Figure 1. For the geometries of figures 2 and 3, with low slant angles, the BH is being viewed more from the side, and the vertical dimension of the flag is not as reduced as for a higher slant angle. For the stripes to subtend 1 arc-min, the fighter would have to view the stripes perpendicularly from a range of 501 ft. For the stars to subtend 1 arc-min, the viewing range would have to be 322 ft.

Dimensions of the Black Hawk

Based on the dimensions of the Black Hawk, the fuselage length of 50 ft, 7.5 in would subtend 155.6 arc-min from a viewing distance of 1118 ft, the fuselage width with ESSS of 20 ft, 2 in, would subtend 62.0 arc-min, and the fuselage height of 9 ft, 5 in would subtend 29.0 arc-min. For objects of moderate contrast, they would have been easily visible.

We estimated, using the profiles of Black Hawks in TM 55-1520-237-10, areas from a side or plan view to be 290 ft², and 100 ft² from the front view. At 1118 ft, the plan or side angular area would be 3.76 E+04 arc-min², and the front angular area would be 1.30E+04 arc-min². The VIDEM model and other aircraft detection models are based on the diameter (α) of a disk equivalent in area to the area that is actually projected by the aircraft. For VIDEM, for foveal viewing the contrast threshold (C_T) of the target is given by:

$$C_T = 0.0334 + 0.409 / \alpha^2$$

Therefore, the Blackhawk contrast threshold is not elevated significantly for short ranges of the geometries we specifically examined (estimated contrast thresholds at the 3 slant ranges are shown in table 1). Threshold is predicted to be 3.34%. C_T is elevated using this equation only when the projected angular size is much smaller. For example, using VIDEM, at 3 nautical miles, estimated alpha is 3.6 arc-min for a side view of the helicopter, and the contrast threshold is predicted to be 6.5%.

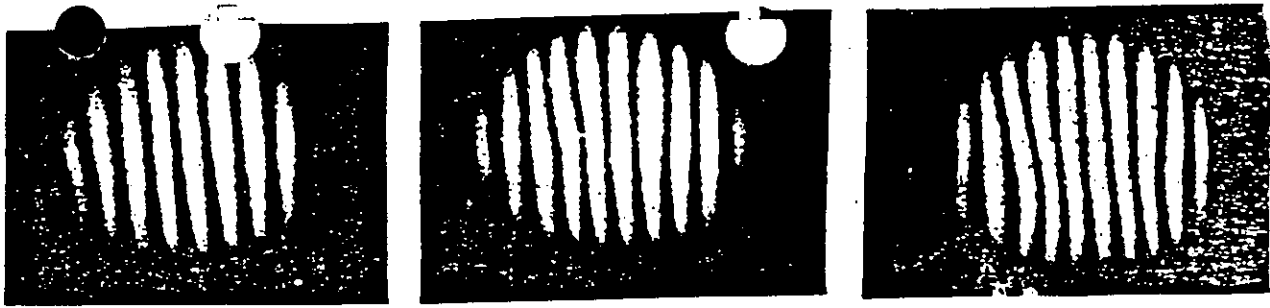


ATTACHMENT 2

Military Specification Requirements for Aircrew Visor Optical Distortion



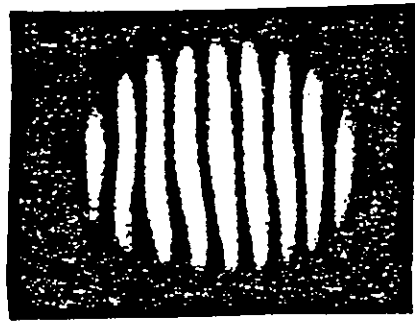
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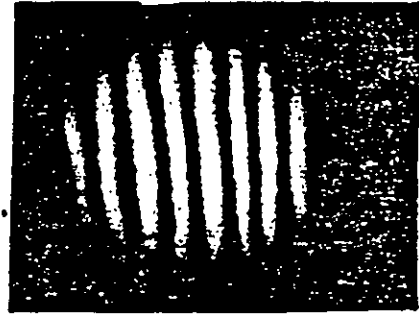
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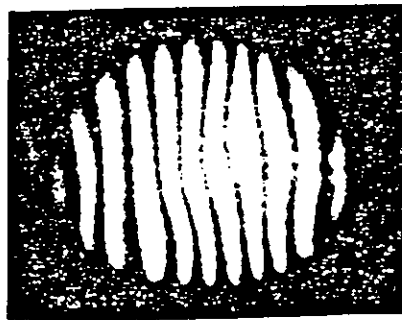


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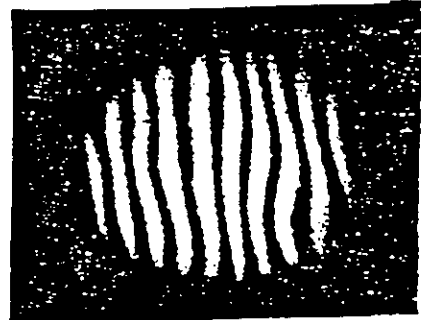


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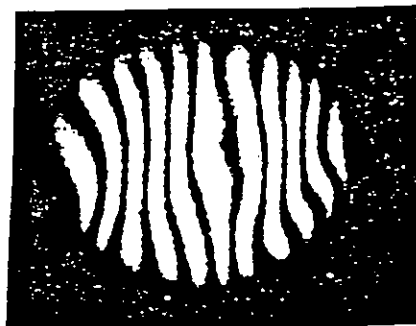
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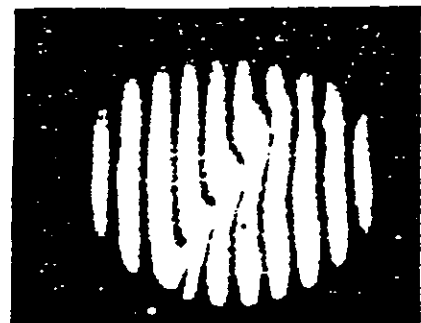
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7



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9

Figure 7. Examples of acceptable (1-5) and unacceptable (6-9) shearing interferometric optical distortion patterns as stated in MIL-V-43511C.

STATEMENT OF QUALIFICATIONS

I am Shari R. Thomas, Ph.D., assigned to the Visual Psychophysics Branch, Optical Radiation Division, Occupational and Environmental Health Directorate, Armstrong Laboratory, Brooks AFB, TX, as a Research Psychologist. I am a Technical Advisor to the AFR 110-14 Accident Board, investigating the crash of two U.S. Army Black Hawk helicopters and the possible involvement of U. S. fighter aircraft in the crash of these helicopters in the northern No-Fly-Zone of Iraq on 14 April 1994. I have held various positions as a vision science researcher in U.S. universities, as a government contractor, and as a U.S. Air Force civil servant. I am currently the Personnel Protection Project Manager for the Visual Psychophysics Branch and an expert on laser eye protection compatibility with military aircraft lighting. I have been involved in vision research for over twelve years, and I have published over 20 open literature journal articles and military limited distribution technical reports. I am a consultant to the American National Standards Institute Subcommittee on Sunglass Standards and the Food and Drug Administration on commercial sunglass standards, and I am a Fellow of the American Academy of Optometry.

9 May 94
(Date)

Shari R. Thomas
(Signature)

CURRICULUM VITAE

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University of Alabama at Birmingham Birmingham, AL	M.S.	1986	Physiological Optics
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M.S. THESIS: Spectral sensitivity of the cat using an increment threshold procedure employing small spot stimuli.

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Laser Safety Officer: Category I and Category II - Nov 94

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Honors Society of the University of Alabama at Birmingham, 1989

American Optometric Foundation Ezell Fellow, 1986, 1987, 1988

National Eye Institute Pre-doctoral Fellow, 1986, 1987, 1988

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Psi Chi (National Honor Society of Psychology Majors)

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National Science Foundation
Food and Drug Administration (Sunglass Standards) ,
American National Standards Institute (Sunglass Standards Subcommittee)
Human Systems Center Vision Enhancement and Eye Protection Integrated Product Team
Armstrong Laboratory Aeromedical Vision Standards Integrated Product Team
Armstrong Laboratory Night Vision Device Integrated Product Team

INVITED PRESENTATIONS:

- Thomas, S.R. & Cartledge, R.M. "Laser Eye Protection Aircraft Lighting Compatibility." Comanche Comanche Cockpit Compatibility Issues Meeting, AMSAT-R-NST, St. Louis, MO, 13 May 94.
- Thomas, S.R. "Laser weapons: Threats, aircrew susceptibility, and eye protection." 422nd Test and Evaluation Squadron and USAF Weapons School, Nellis AFB, NV, 19 - 22 May 94.
- Thomas, S.R. "Aircrew susceptibility to lasers and laser eye protection." Senior Supervisors in Physiology Symposium, Brooks AFB, TX, April 12, 1994.
- Thomas, S.R. "Laser Weapons: Threats, aircrew susceptibility, and eye protection." Operational Problems in Aerospace Physiology Conference, Brooks AFB, TX, April 7, 1994.
- Thomas, S.R. and Barrett, A. "Laser hazards, laser safety, and laser eye protection." Air National Guard Test Center, Tuscon, AZ, April 5-6, 1994.
- Thomas, S.R. "Laser threats, aircrew susceptibility, and eye protection." Air National Guard Syllabus Conference, Boise, ID, February 22-24, 1994.
- Thomas, S.R. "Laser weapons: Threats, aircrew susceptibility, and eye protection." 184th Figher Group, Kansas Air National Guard, McConnell AFB, KS, February 6, 1994.
- Thomas, S.R. "Ocular laser bioeffects and eye protection." University of Alabama at Birmingham School of Optometry, Birmingham, AL, January 25, 1994.
- Thomas, S.R. "Situational awareness of laser threats, aircrew susceptibility, and laser eye protection." United States Air Force Fighter Weapons School and the 57th Test Group, Nellis AFB, NV, November 8 - 9, 1994.
- Thomas, S.R. "Laser threats, aircrew susceptibility, and laser eye protection." 58th Fighter Wing Mission Enhancement and Safety Day, Luke AFB, AZ, September 30, 1993.
- Thomas, S.R. "Laser threats, aircrew susceptibility, and laser eye protection." 46th Test Wing and 33rd Fighter Wing, Eglin AFB, FL, April 27-28, 1993.

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May 9, 1994

Thomas, S.R. "Laser threats, aircrew susceptibility, and the perceptual effects of laser eye protection." Operational Problems in Aerospace Physiology Symposium, Brooks AFB, TX, April 22, 1993.

Thomas, S.R. "Aircrew susceptibility to lasers and laser eye protection." 461st Fighter Squadron, Luke AFB, AZ, April 2, 1993.

Thomas, S.R., & Cartledge, R.M. "Laser eye protection and aircraft lighting compatibility." Air Force Flight Test Center Crew Station Steering Group Cockpit Display Conference, Edwards AFB, CA, March 31, 1993.

Thomas, S.R. "Laser eye effects and situational awareness." 58th Fighter Wing, Luke AFB, AZ, September 8, 1992.

Thomas, S.R. "Laser eye protection program: Cockpit compatibility investigations." U.S. Air Force Flight Test Center Cockpit Station Steering Group, Edwards AFB, CA, June 2, 1992.

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May 9, 1994

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Loop, M.S., Millican, C.L., & Thomas, S.R. (1987). Photopic spectral sensitivity of the cat. *J. Physiol.*, 382, 537-553.

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STATEMENT OF QUALIFICATIONS

I am Maj Leon N. McLin, Jr., O.D., M.S., assigned to the Visual Psychophysics Branch, Optical Radiation Division, Occupational and Environmental Health Directorate, Armstrong Laboratory, Brooks AFB, TX, as a Research Optometrist. I am a Technical Advisor to the AFR 110-14 Accident Board, investigating the crash of two U.S. Army Black Hawk helicopters and the possible involvement of U.S. fighter aircraft in the crash of these helicopters in the northern No-Fly-Zone of Iraq on 14 April 1994. I have been an optometrist for 17 years, and have worked as a researcher investigating the effects of laser light on performance for the last 7 years. I am currently the Personnel Susceptibility Project Manager for the Visual Psychophysics Branch. I am a Fellow of the American Academy of Optometry.

9 May 94

(Date)

Leon N. McLin, Jr.

(Signature)

CURRICULUM VITAE

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DATE: May 8, 1994

EDUCATION:

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<u>School</u>	<u>Degree</u>	<u>Year</u>	<u>Major Area</u>
University of California, Berkeley, Berkeley, CA	M.S.	1987	physiological optics
Pennsylvania College of Optometry, Philadelphia, PA	O.D.	1977	optometry
Temple University, Philadelphia, PA	B.A.	1972	biology

Significant short courses:

Houston Ocular Therapeutics Course, April 94
Laser Safety Training, November 93
Systems Engineering, November 92
Intermediate Systems Acquisition Management Course, February 92
Laser Microwave Hazards Course, U.S. Army Environmental Health
Agency, April 89
Introduction to Systems Acquisition Management, August 88
Laser Hazard Assessment Course, Brooks AFB, January 88
Ocular Therapeutics, Pennsylvania College of Optometry, June 84

Professional Military Education (PME):

Air Command and Staff College	1989
Squadron Officer School (in residence)	1983

LEON N. McLIN, JR.
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PROFESSIONAL EXPERIENCE:

<u>Dates</u>	<u>Employer</u>	<u>Position</u>
Nov 92 - present	USAF	Personnel Susceptibility Project Manager Armstrong Laboratory/OEOV Brooks AFB, TX 78235-5215
Jan 92 - Nov 92	USAF	Commander's Action Group HQ Human Systems Center/CSX Brooks AFB, TX 78235-5000
Sep 87 - Jan 92	USAF	Research Optometrist Armstrong Laboratory/OEDL Brooks AFB, TX 78235-5000
Sep 81 - Aug 85	USAF	Chief, Optometry Services USAF Hospital, K. I. Sawyer K. I. Sawyer AFB, MI 49843
Jun 77 - Sep 81	USAF	Chief, Optometry Services USAF Hospital, Cannon Cannon AFB, NM 88101

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LICENSURE: Pennsylvania 1977 optometrist
Maryland 1977 optometrist

CERTIFICATION:
Acquisition Professional Development Program, Level II, Certification in Systems Planning,
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Acquisition Professional, Level I, Certification in the functional specialty of Science and
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HONORS:

Optometric Recognition Award (ORA), 1985, 1987, 1988, 1990, 1991, 1992, 1993
Air Force Meritorious Service Medal, 1992
Air Force Commendation Medal, 1980 and 1985
Senior Biomedical Science Corps Badge, 1984
Chief Biomedical Sciences Corps Badge, 1990
Beta Sigma Kappa (national honor fraternity for optometry), 1974
Fellow, American Academy of Optometry
Vice president(1989-1990), president (1990-1991), Alamo Triservice Optometric Society

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PROFESSIONAL AFFILIATIONS:

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American Optometric Association
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Beta Sigma Kappa (national honor fraternity for optometry)
Air Force Association

PRESENTATIONS:

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- McLin, L.N. Ocular tracking and visual acuity with a central scotoma. Presented at the South Texas Symposium on Human Factors and Ergonomics, University of Texas at San Antonio, San Antonio, Texas, October 23, 1992.
- McLin, L.N. and Rhodes, J.W. Visual acuity with central simulated scotomas vs real retinal lesions. Presented at the annual meeting, Association for Research in Vision and Ophthalmology, Sarasota, Florida, May 3, 1992.
- McLin, L.N. Visual and performance effects of lasers. Presented at the 14th USAF Optometry Seminar, 3790th Medical Service Training Wing, Department of Biomedical Sciences, Sheppard AFB, Texas, November 5, 1991.
- McLin, L.N. and Rhodes, J.W. Visual acuity with simulated scotomas. Presented at the 13th Annual Lasers on the Modern Battlefield Conference, Letterman Army Institute of Research, Presidio of San Francisco, California, October 23, 1991.
- McLin, L.N. Simulations of laser effects in Counter Target Acquisition System - Phase 2 (CTAS-2). Presented at the 13th Annual Lasers on the Modern Battlefield Conference, Letterman Army Institute of Research, Presidio of San Francisco, California, October 22, 1991.

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- McLin, L.N. Vision research at AL/OEDL - an overview. Presented at meeting "Visual Issues in Training and Simulation" hosted by Armstrong Laboratory, Aircrew Training Research Division, Williams AFB, at Mesa, Arizona, October 1, 1991
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- McLin, L.N. Tracking performance with a simulated central scotoma. Presented at Periopsia, University of Houston, College of Optometry, Houston, Texas, June 14, 1991.
- McLin, L.N. Tracking performance with a central simulated scotoma. Presented at Armstrong Laboratory Advisory Group Conference, "Applied Spatial Vision Models for Target Detection and Recognition," San Antonio, Texas, May 8, 1991.
- McLin, L.N. Tracking performance with a central simulated scotoma and the development of a preferred retinal locus. Presented at the annual meeting, Association for Research in Vision and Ophthalmology, Sarasota, Florida, April 30, 1991.
- McLin, L.N., Effect of target path difficulty and practice on the ability to track with an artificial scotoma. Presented at the 12th Annual Lasers on the Modern Battlefield Conference, Letterman Army Institute of Research, Presidio of San Francisco, California, October 22, 1990.
- McLin, L.N. Operational implications of lasers. Presented at the 61st Annual Scientific Meeting of the Aerospace Medical Association, New Orleans Marriott Hotel, New Orleans, LA, May 16, 1990
- McLin, L.N., Barsalou, N., Beneditz, D., Varner, D., Brakefield, J., and Nelson, M. Visualization of Laser Effects. Presented at the 13th USAF Optometry Seminar, 3790th Medical Service Training Wing, Department of Biomedical Sciences, Sheppard AFB, Texas, February 8, 1990.
- McLin, L.N. and Farrer, D.N. Impact of laser lesions on target acquisition and tracking. Presented at the Tenth Annual Lasers on the Modern Battlefield Conference, Letterman Army Institute of Research, Presidio of San Francisco, California, October 18, 1988.

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- McLin, L.N., Schor, C.M., and Kruger P. Volitional and size induced changes of accommodation and vergence. Presented at the annual meeting, Association for Research in Vision and Ophthalmology, Sarasota, Florida, May, 1987.
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- Tsuetaki, T., Schor, C.M., and McLin, L.N. Tonic adaptation of accommodation reduces accommodative vergence. Presented at the annual meeting, Association for Research in Vision and Ophthalmology, Sarasota, Florida, May, 1986.

PUBLICATIONS:

- Thomas, S.R., McLin, L.N., Garcia, P., LaPage, C., Apsey, D.A. Optical characteristics and visual consequences of laser eye protection. *Optometry and Vision Science*, December 1993 **70**, 98 (Abstract only).
- Thomas, S.R., Ercoline, W.R., Poe, D., Graham, M.R., Patterson, J.A., McLin, L.N. The effects of laser eye protection devices (LEPDs) on simulated and actual F-15E cockpit visibility, Proceedings of the Thirtieth Annual Symposium SAFE Proceedings, November 2-4, 1992, SAFE Association, 4995 Scotts Valley Road, Yoncalla, Oregon 97499-0490, 45-57.
- Thomas, S.R., and McLin, L.N. Physical measurements characterizing the visual displays and laser bioeffects simulations used in the Counter Target Acquisition System Test Phase 2 (CTAS-2), AL-TR-1991-0147, May 1992, Armstrong Laboratory, Brooks AFB, TX 78235-5000
- McLin, L.N. and Rhodes, J.W. Visual acuity with central simulated scotomas vs real retinal lesions. *Investigative Ophthalmology and Visual Science ARVO Supplement*, March 1992, **33**, 724, (Abstract only).
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- Griffin, J.R., McLin, L.N., and Schor, C.M. Photographic method for Bruchner and Hirshberg testing. *Optometry and Vision Science*, 1989, **66**, 467-473.

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- McLin, L.N., Schor, C.M., and Kruger, P. The effect of size changes (looming) on accommodation and vergence. *Vision Research*, 1988, **28**, 883-898.
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- McLin, L.N., Schor, C.M., and Kruger P. Volitional and size induced changes in accommodation and vergence. *Investigative Ophthalmology and Visual Science ARVO Supplement*, March 1987, **28**, 317. (Abstract only).
- Griffin, J.R., McLin, L.N., and Schor, C.M. Photographic method for strabismus detection- effectiveness of Bruchner and Hirshberg testing. *American Journal of Optometry and Physiological Optics*, October 1986, **63**, 110P. (Abstract only).
- Tsuetaki, T., Schor, C., and McLin, L. Tonic adaptation of accommodation reduces accommodative vergence. *Investigative Ophthalmology and Visual Science ARVO Supplement*, March 1986, **27**, 79. (Abstract only).

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TAB O

ADDITIONAL SUBSTANTIATING DATA REPORTS

	O-1
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O-1 UH-60 Black Hawk 88-26060	O-3
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O-9 Crash Site Analysis Technical Report	
O-10 Technical Report, F-15C IFF/AAI Systems (See also Classified Addendum)	
O-11 Technical Report UH-60 Black Hawk IFF/AAI Systems	

TECHNICAL REPORT

US ARMY UH-60 CRASH SITES

I. Introduction: The purpose of this report is to describe the physical characteristics of the crash sites of two US Army Black Hawk helicopters; and to describe the dynamics of each crash by wreckage analysis.

II. Background: The accident involved two U.S. Army UH-60 helicopters flying at contour flight altitudes, and in a staggered trail left formation. Both helicopters impacted in the mountainous terrain of Northern Iraq after being hit by air-to-air missiles. Eagle 02, the trail helicopter, was struck first, followed by Eagle 01. The helicopters crashed 1.2 nautical miles apart (diagram 1).

III. Evaluation and Determination:

CRASH SITE #1 UH 60 Serial #87-26000

(1) Eagle 02 crash site description (71 nautical miles southeast of Zakhu, coordinates North 36 degrees, 46 minutes, 11 seconds, East 044 degrees, 05 minutes, 33 seconds).

(a) The crash occurred on the floor of a valley that runs northwest to southeast and is approximately 2,000 feet wide at the point of impact. Mountains skirting the valley average 4000 feet in height. A trail (road) constructed of rock and mud skirts the southern side of the valley floor and intersects a paved road 1 1/2 miles north west of the accident site.

(b) The helicopter impacted a terraced portion of the valley floor which was cultivated. The terrace is constructed of rock and approximately five feet high. No trees were located at the point of impact.

(2) Flight Path Wreckage Distribution

(a) Eagle 02 was proceeding along a valley on a heading of between 100 and 120 degrees, with mountainous terrain on either side. Preliminary on site examination of the airspeed indicator, that was found in the wreckage, revealed that the airspeed at the time of impact was approximately 72 knots per hour. The airspeed indicator has been sent to Corpus Christi Army Depot for further teardown analysis. Using eye witness information as to where the helicopter was seen and location/elevation data obtained from a Global Positioning System (GPS), the flight altitude was determined to be approximately 122 feet Above Ground Level (AGL) at the time of missile impact. The helicopter entered a right yaw that eventually corrected back to a heading of approximately 100 degrees, and caught fire. The angle of impact was computed to be approximately eight degrees (diagram 2).

(b) The distribution of wreckage started 1,320 feet from where the helicopter struck the ground, and was scattered along the side of a ridge parallel to the route of flight (diagram 3, 4). The scatter pattern began at 150 feet above the floor of the valley, descended down the face of the ridge as the helicopter descended, and continued along the valley floor until the helicopter impacted the ground.

(c) The first piece of wreckage found was chaff out of the chaff dispenser located on the left side of the tail boom just aft of the tail boom attachment points, station 520 (diagram 5, line 1). A significant number of pieces of Plexiglass from a cargo door window, station 343, (diagram 4, line 2) were found 60 feet further in the direction of flight, followed by a 10" x 10" piece of the helicopter window frame portion of a cargo door. A larger piece of a left side cargo door was found along the flight path and retrieved during one of the initial searches of the accident site. The two pieces of cargo door appear to match, and both have similar shrapnel damage from missile burst. The cowling from the left side of the fuselage, vicinity of the tail boom, station 455, (diagram 5, line 3) and Auxiliary Power Unit (APU), station 443, (diagram 5, line 4) as well as pieces of the APU were found along the route of flight from 1,095 feet to within 258 feet of helicopter impact. The upper fuselage at the tail boom attachment points, station 490, (diagram 5, line 5) and the APU access doors, station 420, (diagram 5, line 6) both revealed shrapnel damage. A 3' x 4' portion of the left side of the tail boom at the tail boom attachment point, station 500, (diagram 5, line 7) was found 250 feet from the helicopter initial impact point.

(3) Wreckage at Point of Ground Impact.

(a) The helicopter's initial impact was into the bank of a stream bed. Damage analysis and eye witness information indicated that the helicopter was in a left roll, a relatively level pitch attitude was on fire in the vicinity of the APU, and did not enter a decelerative attitude prior to impact. The helicopter was subsequently consumed by fire. Wreckage associated with the lower left side of the crew compartment, fuselage and the tail boom were found within 10 feet of the initial impact point. All four tail rotor paddles sustained rotational damage either from helicopter debris coming off during flight or during the ground impact sequence. Pieces of the main rotor system were found in the initial impact area, but due to extensive foot traffic prior to our investigation, no ground scars caused by main rotor blade impact could be found.

(b) Debris from the main fuselage was found on a terraced area 5 feet above and 51 feet beyond the initial impact point in the direction of flight. The main fuselage was totally consumed by fire. The main transmission was found with the mast and main rotor head attached, 96 feet from the initial impact point. All four main rotor blades were broken off at the main rotor hub and sustained substantial fire damage. A partial section of the cargo compartment floor pan was found 126 feet from initial impact in the direction of flight. The number two engine was found 184 feet from initial impact on the side of a 15 degree slope. The engine had no burn damage and minor impact damage to the exhaust section.

(4) Determination:

(a) It was determined that the missile detonated on the left side of the UH-60 fuselage in the vicinity of the tail boom attachment point, station 443.5, (diagram 5, line 4) for the following reasons:

1. A significant amount of left side fuselage debris from in, and around the APU area was scattered along the route of flight.

2. Left side fuselage cowling, the left cargo door, and the APU access doors have shrapnel damage.

3. APU debris and APU parts were found along the route of flight.

(b) The missile approached the helicopter from below the main rotor system. No main rotor debris was found along the route of flight indicating that the rotor blades were either undamaged or they did not start to deteriorate.

(c) Although the helicopter main fuel tank was probably damaged by shrapnel, the detonation did not occur in the fuel tank. Some fire was observed coming from the APU area prior to impact but no explosion was reported.

(d) Either the pilot in command and/or the copilot were incapacitated after the missile detonation, or the flight controls were compromised by shrapnel. No decelerative flare was observed prior to ground impact.

CRASH SITE #2 UH-60 Serial #88-26060

(1) Eagle 1 crash site (72 nautical miles southeast of Zakhu, Iraq, coordinates North 36 degrees, 46 minutes, 04 seconds, East 044 degrees, 05 minutes, 33 seconds)

(a) The crash occurred on the base of a mountain range, in a draw that runs north-south up the side of the mountain. An active intermittent stream runs from the mountain ridge down the 48 degree slope of the draw. The draw is formed by steep terrain (45 degree slope) on both sides. The terrain is characterized as extremely rocky with large boulders and thick vegetation, both grass and trees. The trees are on an average 8-10 feet in height.

(b) The helicopter impacted on a 45 degree slope and in trees. A man made terrace approximately two feet high, constructed of rock, runs through the point of impact.

(2) Flight Path Wreckage Distribution

(a) Eagle 01 was proceeding down a valley on a heading of between 100 and 120 degrees. An eye witness indicated that after the trail helicopter was struck by a missile, the lead

helicopter made a series of rapid left and right banks eventually turning to the left. The helicopter entered a left turn flying up a draw toward a mountain ridge line on the north side of the valley. The aircraft crashed on an approximate heading of 040 degrees. The airspeed could not be determined by analysis of the wreckage due to extensive damage. A section of the main rotor blade cut three trees on the side of a ridge line 678 feet from helicopter ground impact. Because of the dynamics of the main rotor system, it is likely that the section of blade that struck the trees remained at the same elevation (altitude) as the rotor disk until it hit the trees. The location of the tree strike would place the helicopter at approximately 200 feet above the floor of the draw at the time of main rotor system disintegrated. The helicopter heading at the time of ground impact was determined to be 040 degrees. The angle of impact, approximately 56 degrees; was computed by identifying a point on the surrounding terrain (trees that were cut by a three foot section of main rotor blade) that was parallel to the flight path of the helicopter, and measuring distances and elevations.

(b) Two pieces of helicopter debris were found 3027 feet (.6 mile) from the helicopter ground impact point (diagram 7). One was a mounting bracket for the cargo hook swivel bearings, station 370 (diagram 9, line 1), and the other was a piece of cargo compartment sound proofing, station 400 (diagram 9, line 2) with shrapnel damage. The first sign of main rotor blade deterioration (honeycomb) was found 2118 feet from helicopter ground impact. The helicopter began major deterioration approximately 900 feet prior to ground impact losing at least one main rotor blade and part of a tail rotor paddle. Pieces of engine cowling, station 410 (diagram 9, line 3) and fuselage, station 380 (diagram 9, line 4) were scattered over the next 300 feet.

(3) Wreckage at Point of Ground Impact.

(a) The helicopter impacted the side of a mountain on 45 degree sloping terrain and was totally consumed by fire. The wreckage was confined in an area approximately 50 feet in diameter with selected components distributed on a heading of 040 degrees. The small scatter area is indicative of a steep impact angle (56 degrees).

(b) The main fuselage and left engine was found at the initial point of ground impact. The fuselage was consumed by fire. The left engine sustained extensive fire damage. The right engine was thrown free of the wreckage impacting approximately 55 feet from the main fuselage. The location of the engines is an indication that the helicopter impacted left side low, in that the left engine remained at the initial ground impact point, while the right engine was thrown in the direction of flight.

(c) The main transmission with the mast and main rotor hub attached came to rest 41 feet from the main fuselage. Two main rotor blades, although destroyed in the fire, were still attached to the main rotor hub. No evidence of the other two main rotor blades was found at the helicopter ground impact point, however, a significant portion of two blades was found along the flight path.

(d) The tail boom was consumed by the fire. The tail rotor gear box and tail rotor hub were located 41 feet from the main fuselage. All four tail rotor paddles (blades) were broken off at the hub. The tail rotor system, as well as the tail rotor gearbox, routinely depart the helicopter when a severe imbalance condition develops. Because a portion of a tail rotor paddle was lost during flight and the fact that the tail rotor system and tail rotor gearbox did not rip free due to a symmetrical imbalance, it is believed that tail rotor was not being driven just prior to ground impact.

(4) Determination:

a Missile impact occurred along the flight path at the approximate location where extensive helicopter debris began, 909 feet from helicopter ground impact. Parts found previous to this point were blown back during detonation or were moved by visitors to the site.

b The missile went through the main rotor system prior to striking the fuselage. This would explain the extensive main rotor blade damage which occurred prior to the helicopter striking the ground, and is supported by an eye witness account of the missile impact.

c Neither the pilot in command nor the copilot could have controlled the helicopter during the impact sequence due to the destruction of the main rotor system.


DANIEL W. MEDINA, CW5, USA
Technical Advisor

Atch:

1. Dia 1. Overview of both crash sites
2. Dia 2. View of crash site 1
3. Dia 3. Flight path wreckage distribution of crash site 1
4. Dia 4. Main wreckage distribution of crash site 1
5. Dia 5. Component locations of parts found at crash site 1
6. Dia 6. View of crash site 2
7. Dia 7. Flight path wreckage distribution of crash site 2
8. Dia 8. Main wreckage distribution of crash site 2
9. Dia 9. Component locations of parts found at crash site 2

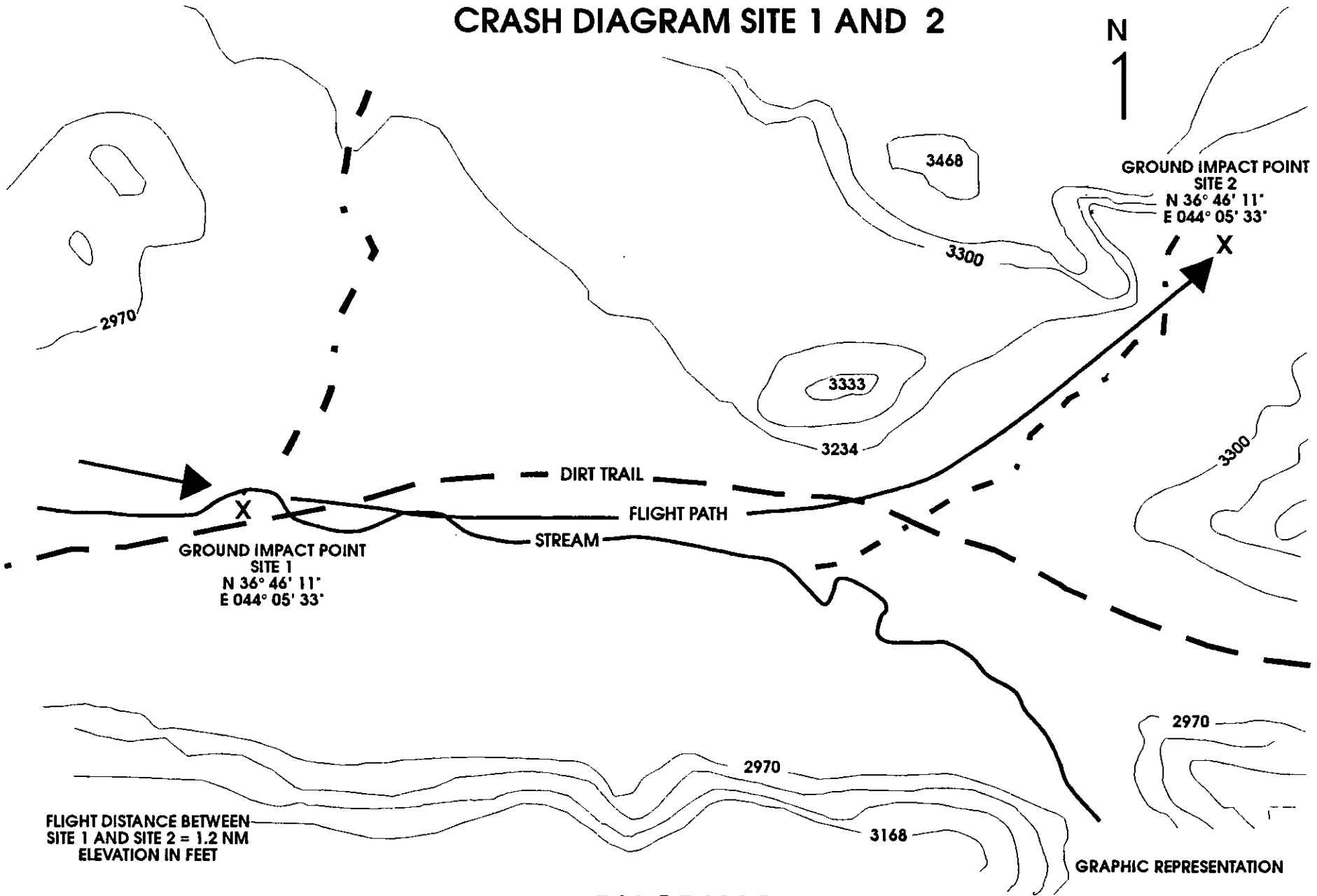
STATEMENT OF CERTIFICATION

I am CW5 Daniel W. Medina, assigned to the US Army Safety Center, Ft Rucker, AL as an accident investigator. I am a technical advisor to the AFR 110-14 Accident Board investigating the crash of two US Army Black Hawk helicopters and the possible involvement of US fighter aircraft in the crash of these helicopters in northern no-fly zone of Iraq on 14 Apr 94. In March 1973 I graduated from the U.S. Army Safety Officer Course conducted by the University of Southern California. I have served 12 years as a safety officer at company and battalion level. I served five years as a safety officer at Army Europe level with the task of training safety officers and evaluating unit safety programs. I have 4400 flight hours as a helicopter pilot.

20 May 94
(DATE)

Daniel W. Medina
DANIEL W. MEDINA, CW5, USA

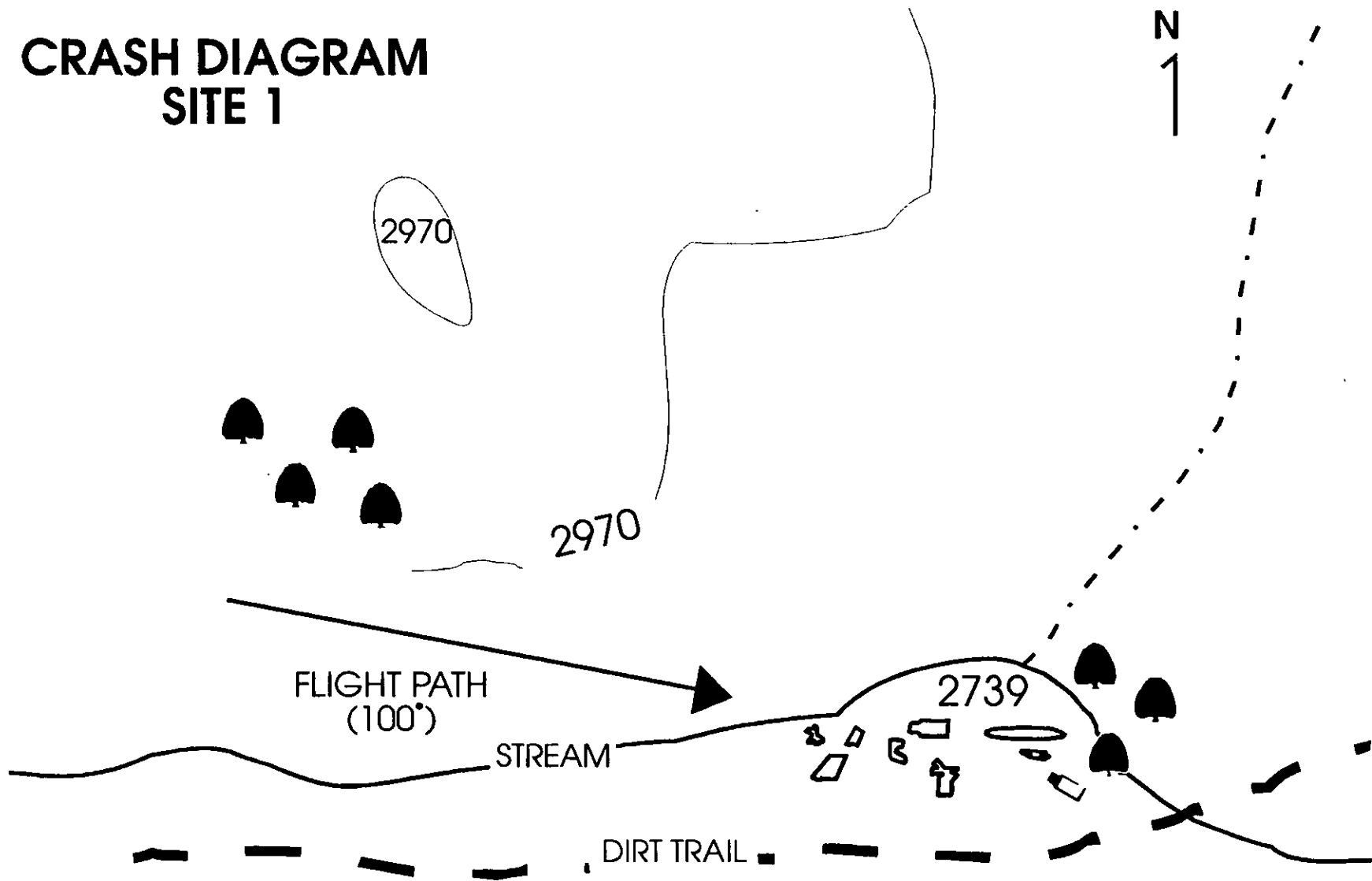
CRASH DIAGRAM SITE 1 AND 2



FLIGHT DISTANCE BETWEEN
SITE 1 AND SITE 2 = 1.2 NM
ELEVATION IN FEET

DIAGRAM 1

CRASH DIAGRAM SITE 1



GROUND IMPACT POINT
SITE 1
N 36° 46' 04"
E 044° 05' 33"

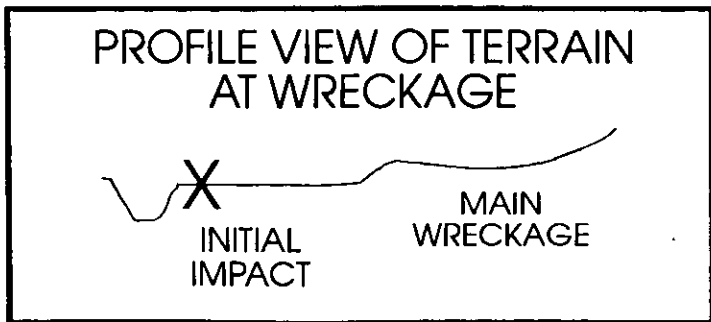


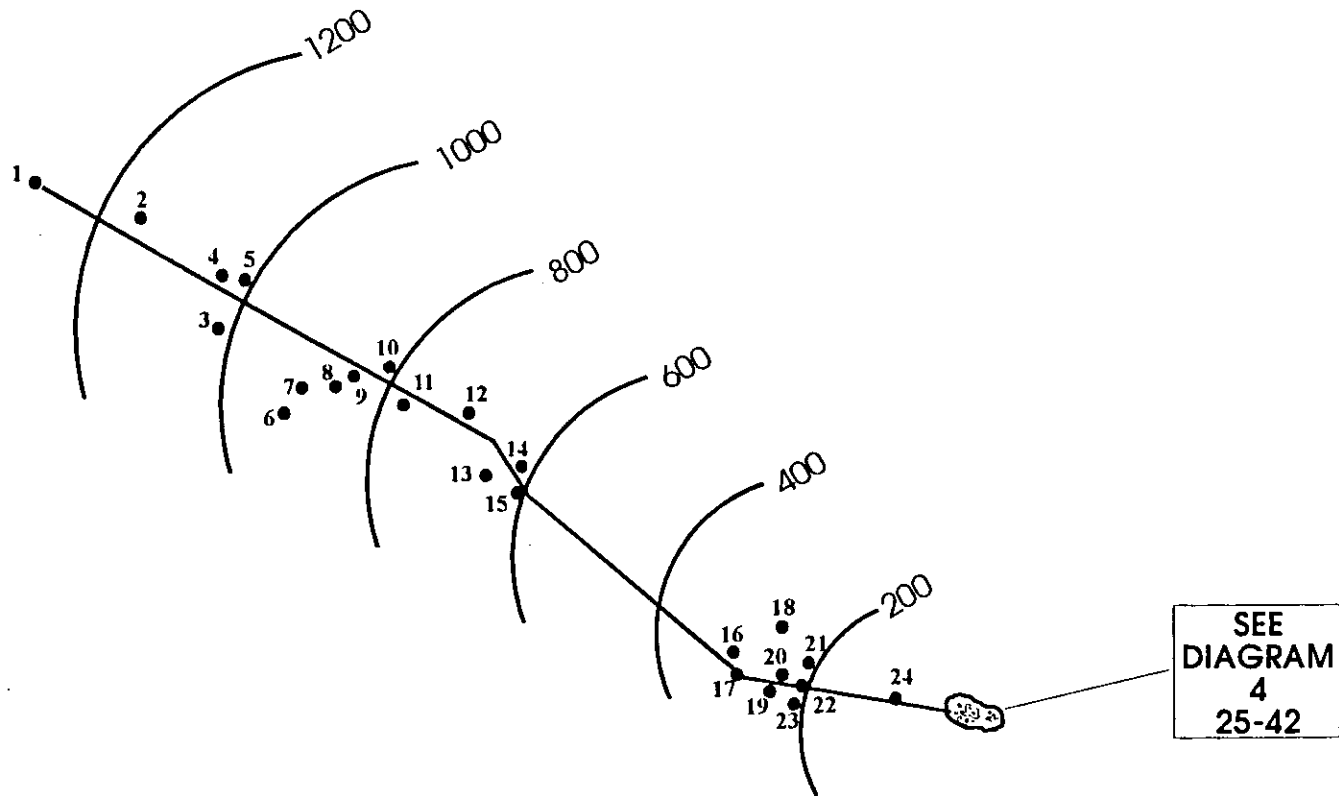
DIAGRAM 2

GRAPHIC REPRESENTATION
ELEVATION IN FEET

FLIGHT PATH WRECKAGE DISTRIBUTION SITE 1 TAIL NO. 87-26000

LEGEND

ITEM	DESCRIPTION	DIST (FD)	DIR (MAG)
1	CHAFF	1320	119
2	CARGO DOOR WINDOW	1200	121
3	SOUND PROOFING, PASS. CPMT	1110	116
4	TOP FUSELAGE COWLING VCTY	1095	120
5	TAIL BOOM	1050	122
6	AFT PIECE OF LEFT CARGO DOOR	1020	113
7	SLEEPING BAG	1020	113
8	VOR ANTENNA	996	116
9	PIECE OF SEAT BELT	936	117
10	SOUND PROOFING, CARGO CPMT	936	118
11	LEFT APU ACCESS DOOR (CUT)	915	121
12	RIGHT APU ACCESS DOOR	873	120
13	APU FIRE DETECT LITE	825	121
14	FUEL CAP RIGHT SIDE	762	121
15	COWLING BEHIND FIRE BOTTLES	690	116
16	SOUND PROOFING PASS. CPMT	684	115
17	APU COMPARTMENT FIREWALL	660	113
18	APX 100 ANTENNA CABLE	360	105
19	PIECE APU INTAKE HOUSING	324	096
20	PIECE APU COMBUSTION CHAMBER	300	102
21	PIECE FUSELAGE SKIN (SMALL)	294	097
22	PIECE FUSELAGE SKIN (SMALL)	258	101
23	ELECTRICAL WIRE (10' LONG)	258	100
24	APU ENGINE PART	258	094
25-42	TAIL BOOM SECTION, LEFT SIDE	129	100
25-42	MAIN WRECKAGE CENTER OF MASS	0	0
43	PIECE OF MISSILE	497	100



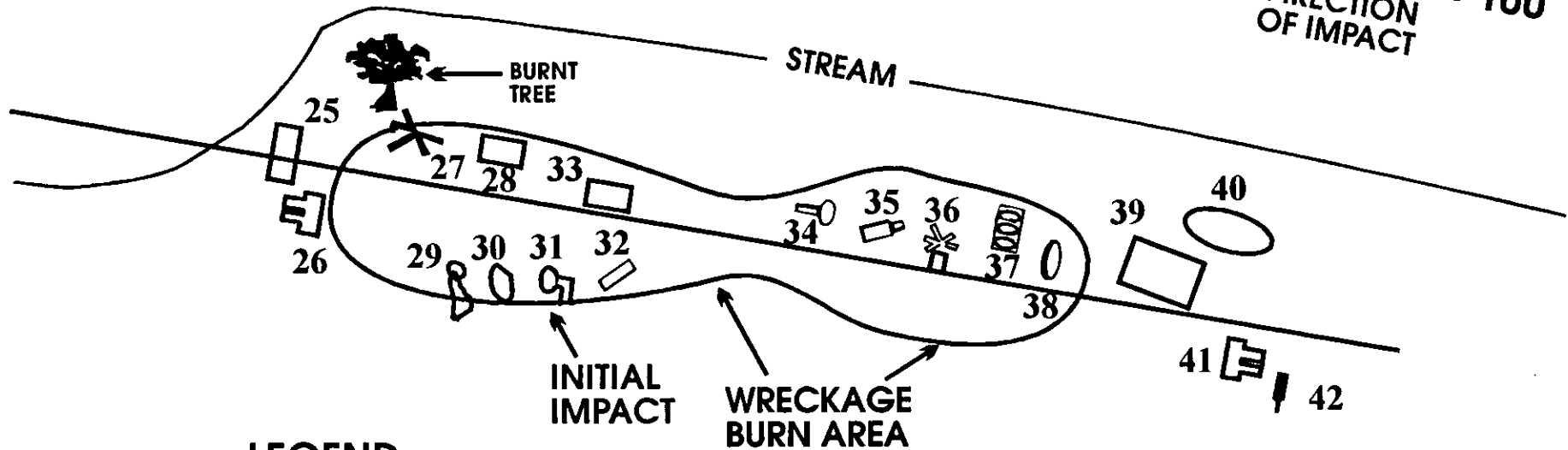
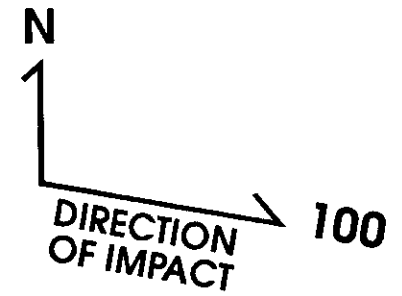
1. DISTANCES ARE IN FEET
2. DIRECTIONS ARE ESTIMATED IN DEGREES MAGNETIC
3. DISTANCES AND DIRECTIONS ARE RELATED TO CENTER OF MASS OF MAIN WRECKAGE

DIAGRAM 3

SITE 1

MAIN WRECKAGE DISTRIBUTION

TAIL NO. 87-26000



LEGEND

ITEM	DESCRIPTION	DIST (FT)	DIR (MAG)
25	RIGHT STABILATOR PART	96	290
26	LEFT ESSS PART	98	280
27	TAIL ROTOR PYLON	56	275
28	TAIL BOOM PART	53	278
29	LEFT WHEEL STRUT	51	255
30	SEARCH LITE	50	258
31	PEDAL, TAIL ROTOR CONTROL	50	258
32	MAIN ROTOR BLADE PART	40	300
33	TAIL BOOM PART	43	278
34	OIL COOLER FAN	15	300
35	LEFT ENGINE	5	300
36	MAIN TRANSMISSION	0	0
37	HYDRAULIC ASSIST MODULE	10	110
38	SLEEPING BAG	13	112
39	CARGO FLOOR PIECE	30	115
40	RIGHT ESSS FUEL TANK	47	108
41	RIGHT ESSS PYLON	75	120
42	RIGHT ENGINE	88	120

SLOPE INFORMATION

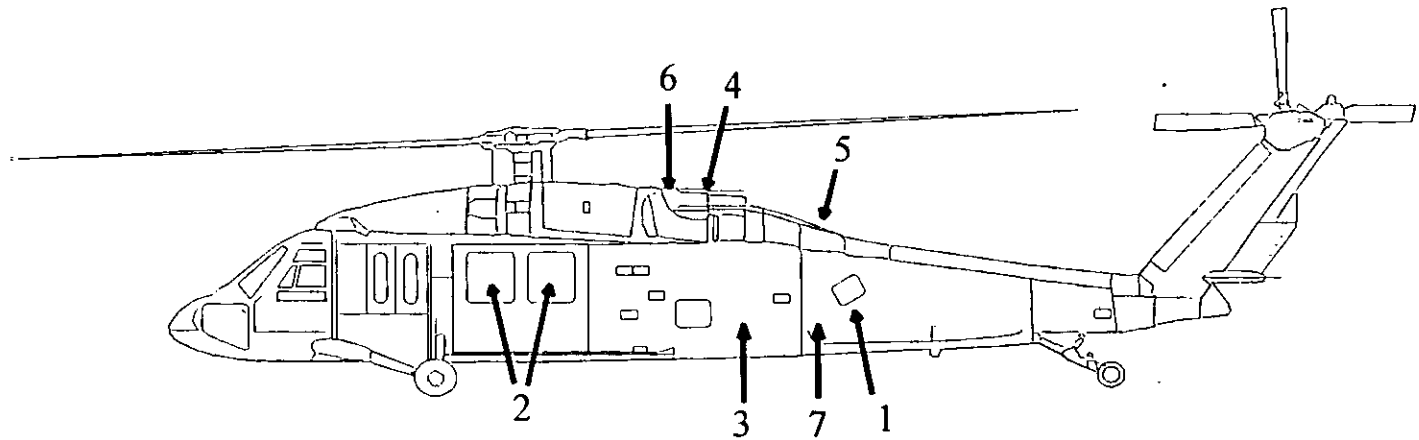
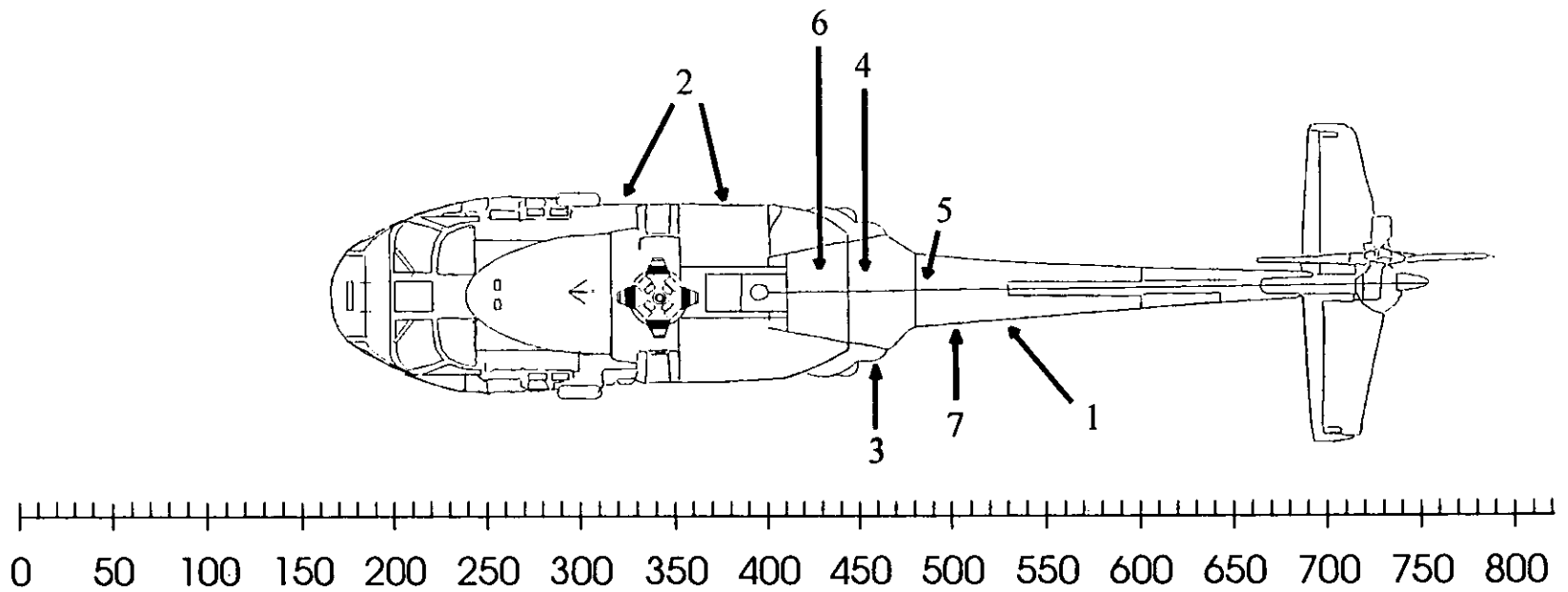
INITIAL IMPACT: 2° DOWN SLOPE TO THE RIGHT OF FLIGHT PATH
 2° UP SLOPE TO THE DIRECTION OF FLIGHT PATH

MAIN WRECKAGE: 5° DOWN SLOPE TO THE RIGHT OF FLIGHT PATH
 0° SLOPE IN THE DIRECTION OF FLIGHT PATH

IMPACT ANGLE BETWEEN FLIGHT PATH AND INITIAL IMPACT POINT: 8°

DISTANCES ARE MEASURED IN FEET
 DIRECTIONS ARE MEASURED IN DEGREES MAGNETIC
 DISTANCES AND DIRECTIONS ARE MEASURED FROM MAIN TRANSMISSION (36)

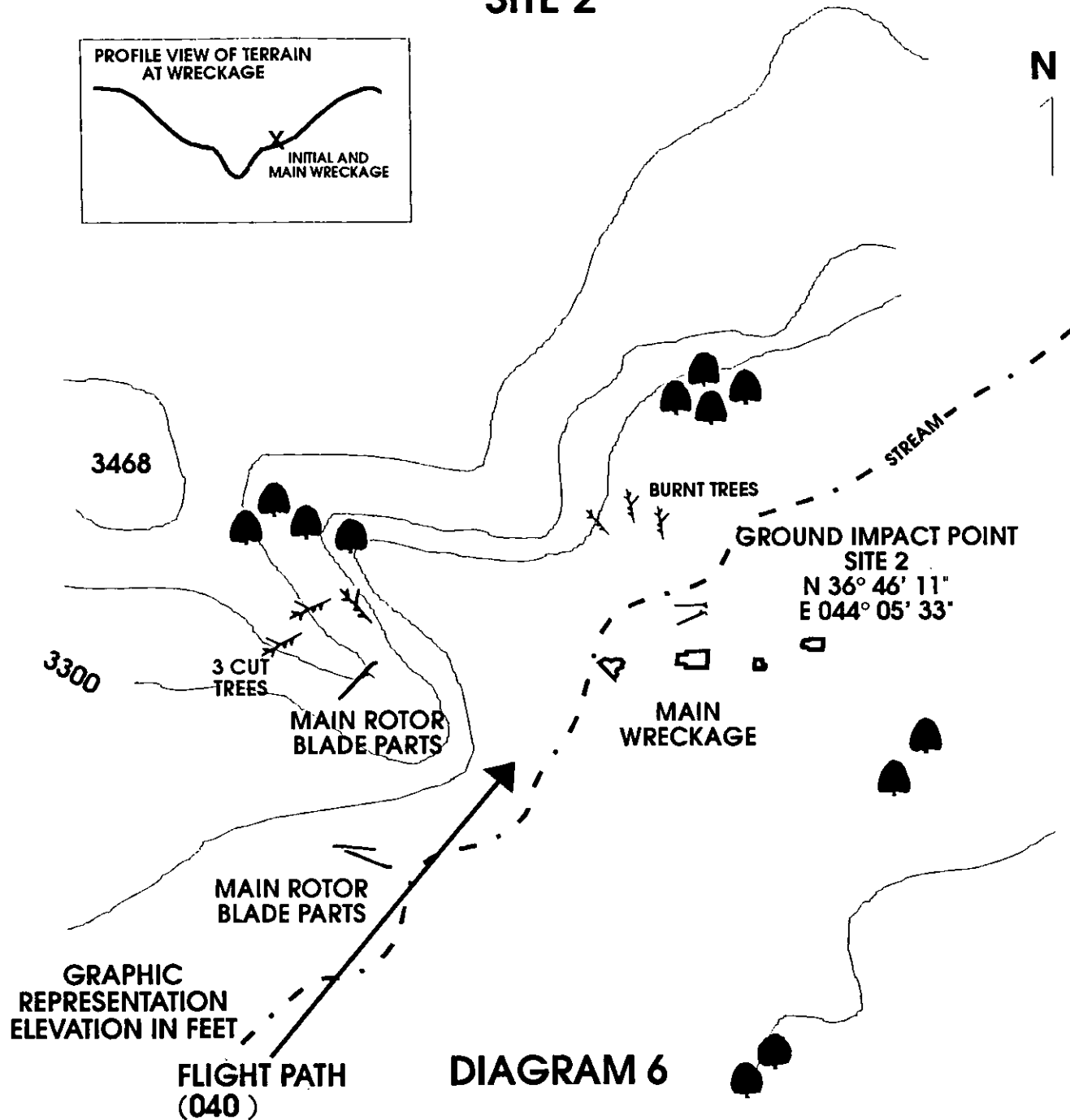
DIAGRAM 4



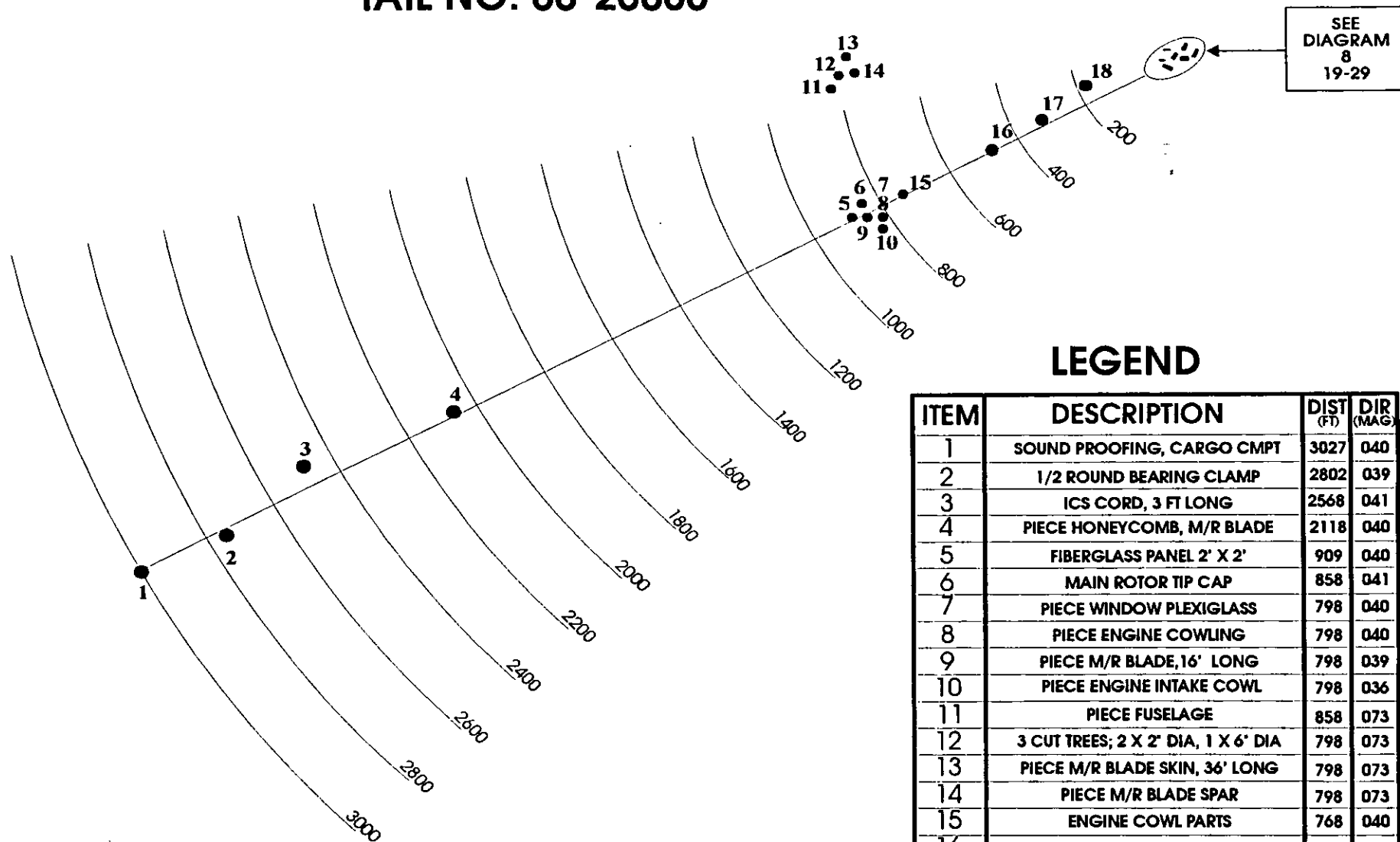
**AIRCRAFT COMPONENT LOCATIONS
TAIL NO. 87-26000**

DIAGRAM 5

CRASH DIAGRAM SITE 2



FLIGHT PATH WRECKAGE DISTRIBUTION SITE 2 TAIL NO. 88-26060



LEGEND

ITEM	DESCRIPTION	DIST (FT)	DIR (MAG)
1	SOUND PROOFING, CARGO CMPT	3027	040
2	1/2 ROUND BEARING CLAMP	2802	039
3	ICS CORD, 3 FT LONG	2568	041
4	PIECE HONEYCOMB, M/R BLADE	2118	040
5	FIBERGLASS PANEL 2' X 2'	909	040
6	MAIN ROTOR TIP CAP	858	041
7	PIECE WINDOW PLEXIGLASS	798	040
8	PIECE ENGINE COWLING	798	040
9	PIECE M/R BLADE, 16' LONG	798	039
10	PIECE ENGINE INTAKE COWL	798	036
11	PIECE FUSELAGE	858	073
12	3 CUT TREES; 2 X 2' DIA, 1 X 6' DIA	798	073
13	PIECE M/R BLADE SKIN, 36' LONG	798	073
14	PIECE M/R BLADE SPAR	798	073
15	ENGINE COWL PARTS	768	040
16	ELECTRICAL CONNECTOR MULTI-WIRE	468	040
17	PIECE T/R BLADE	318	040
18	PIECE COWLING SUPPORT	190	050
19-29	MAIN WRECKAGE CENTER OF MASS	0	0

1. DISTANCES ARE IN FEET
2. DIRECTIONS ARE ESTIMATED IN DEGREES MAGNETIC
3. DISTANCES AND DIRECTIONS ARE RELATED TO CENTER OF MASS OF MAIN WRECKAGE

DIAGRAM 7

SITE 2

MAIN WRECKAGE DISTRIBUTION

TAIL NO. 88-26060

LEGEND

ITEM	DESCRIPTION	DIST (FT)	DIR (MAG)
19	APU DECK	130	480
20	PIECE TAIL BOOM, RIGHT	77	195
21	MIXING UNIT	48	215
22	MAIN FUSELAGE	41	230
23	TAIL ROTOR	41	210
24	LEFT ENGINE	35	235
25	ESSS TANK	32	250
26	MAIN TRANSMISSION	0	0
27	APU ENGINE	35	200
28	GROUND SCAR RIGHT ENGINE	55	100
29	RIGHT ENGINE	71	125

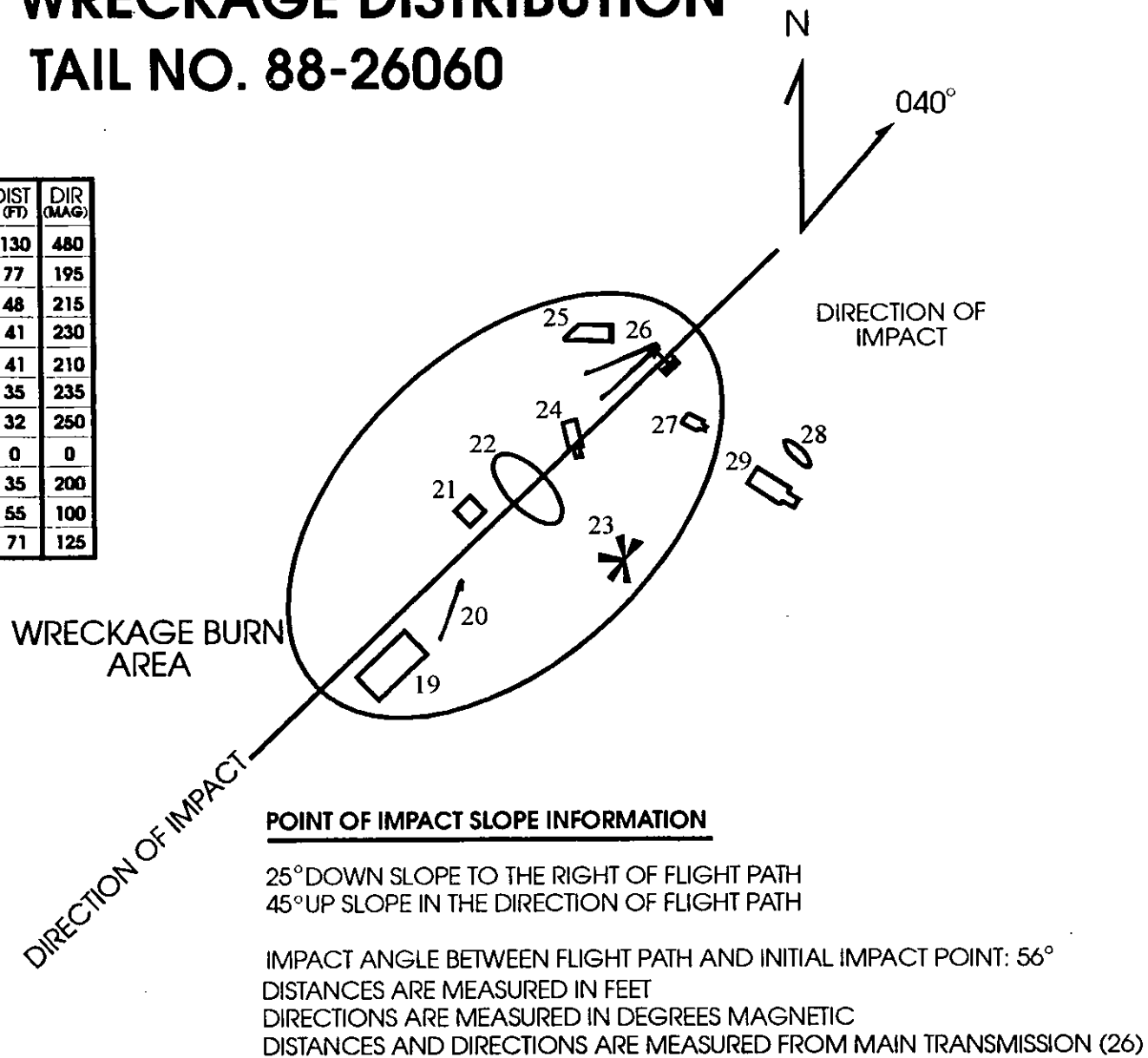
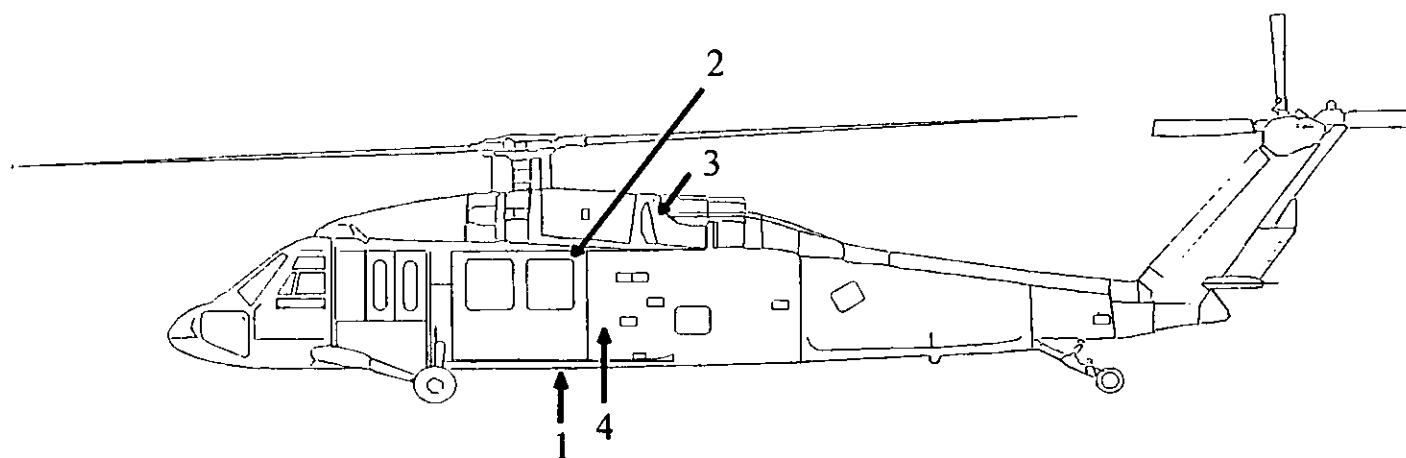
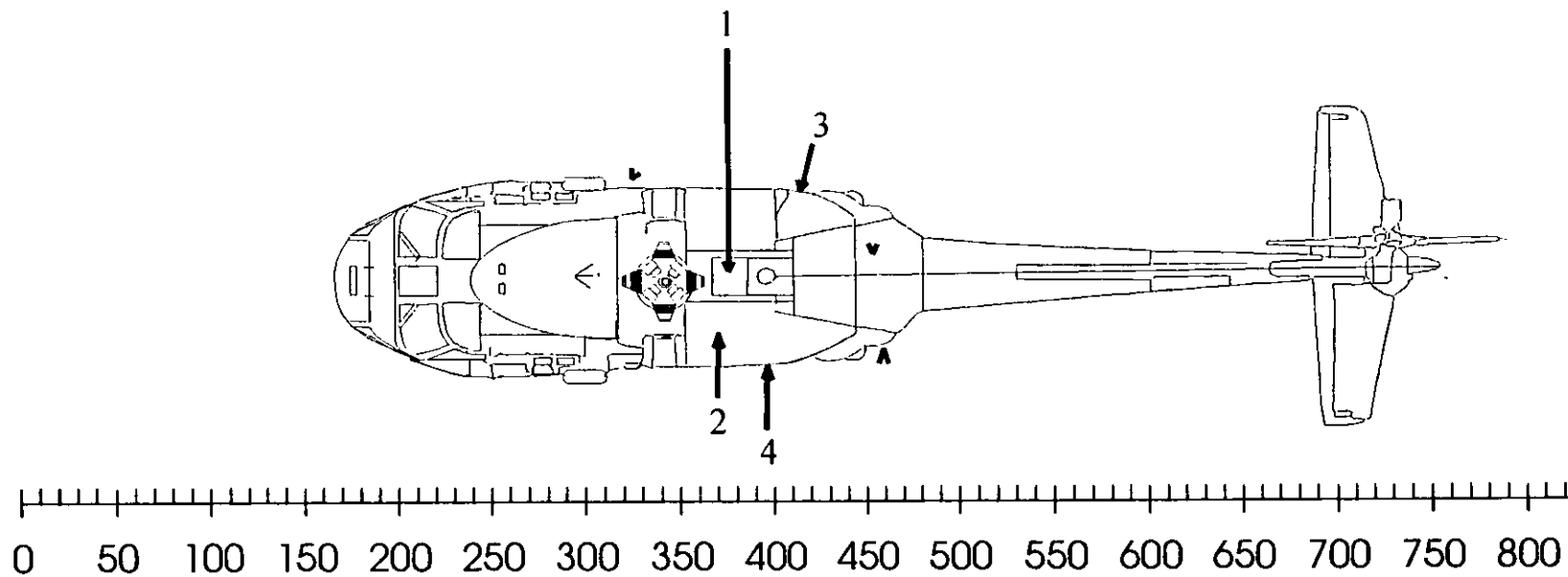


DIAGRAM 8



**AIRCRAFT COMPONENT LOCATIONS
TAIL NO. 87-26060**

DIAGRAM 9

TAB O

ADDITIONAL SUBSTANTIATING DATA REPORTS

	O-1
	O-2
O-1 UH-60 Black Hawk 88-26060	O-3
O-2 UH-60 Black Hawk 87-26000	O-4
O-3 E-3B AWACS	O-5
O-4 F-15C 79-0025	O-6
O-5 F-15C 84-0025	O-7
O-6 Human Factors	O-8
O-7 Medical Reports	O-9
O-8 Optics Report	O-10
O-9 Crash Site Analysis Technical Report	
O-10 Technical Report, F-15C IFF/AAI Systems	
(See also Classified Addendum)	
O-11 Technical Report UH-60 Black Hawk	
IFF/AAI Systems	

Technical Report

F-15 Air-to-Air Identification-Friend-or-Foe (IFF) Interrogation (AAI) System

Aircraft Evaluated: F-15C, Tail Numbers 79-0025 and 84-0025

Incident Date: 14 April 1994

I. INTRODUCTION: The purpose of this evaluation was to determine whether there is an F-15C AAI (APX-76) systems explanation for the report of the lead F-15 pilot that he had a brief positive Mode IV reply, followed by negative reply, while interrogating two UH-60 Black Hawk helicopters using the APX-100 IFF transponder.

II. BACKGROUND: The accident involved the crash of two US Army Black Hawk helicopters, serial numbers 88-26060 and 87-26000, and the possible involvement of US F-15 fighter aircraft, serial numbers 79-0025 and 84-0025, and a US AWACS, aircraft serial number 77-0351, in the crash of these helicopters in the northern No-Fly-Zone of Iraq on 14 April 1994.

III. EVALUATION: A thorough evaluation was conducted of the serviceability of the AAI systems installed on aircraft 79-0025 and 84-0025 on 14 April. (Tab O4b; Tab O5b)

In addition, the F-15C manufacturer, McDonnell Douglas Aircraft Corporation, was contacted to determine if there are any known anomalies with the F-15C AAI system. The Department of Defense (DOD) IFF Program Office at Warner Robins Air Logistics Center, GA was contacted to determine if they were aware of any IFF anomalies that might be relevant to the mishap.

The Theater Air Command and Control Simulation Facility (TACCSF) at Kirtland Air Force Base, NM developed a computer model to simulate the F-15C and UH-60 dynamics during the intercept. The 57th Test Group at Nellis Air Force Base conducted flight testing involving F-15Cs and UH-60s to recreate the electronic identification (EID) portion of the intercept.

IV. DETERMINATION: The AAI systems of both aircraft were evaluated for serviceability. An historical records review, ground functional check, pilot assessment, and teardown of key components was conducted on each aircraft. Information compiled from these efforts indicates both aircraft's AAI systems were most likely serviceable at the time of the mishap. (Tab O4b; Tab O5b) For the purpose of this determination, it was assumed that the AAI systems were functional.

Representatives from McDonnell Douglas Aircraft (MDA) Corporation indicated they were not aware of any known F-15C AAI anomalies that would explain a momentary Mode IV reply and then a negative response for the remainder of an interrogation. MDA did indicate the possibility that IFF replies from two close-proximity targets might overlap, corrupt the encoded reply and be interpreted as a negative reply by the interrogating platform. (Atch 2)

A representative from the DOD IFF Program Office confirmed the theoretical possibility of reply signals from two close proximity targets interfering with each other and preventing the interrogator from receiving either signal. The more likely possibility, according to the representative, is that the interrogating platform would only receive one of the two replies. (Atch 3)

Computer simulation testing at TACCSF indicated that, with the F-15 radar in certain modes, the F-15 AAI system was not consistently capable of successfully interrogating and receiving IFF responses from two UH-60s flying in close proximity (1000 feet apart). (Atch 4)

The simulator results revealed the probability of a IFF response being received by the AAI system was "largely determined by the amount of time the coolie switch is held over during any particular interrogation request." The TACCSF report also specified that "it was often necessary to hold the coolie switch in the interrogate position for several seconds to obtain a response while in Track-While-Scan or Search modes." (Atch 4) The coolie switch is the multi-function switch on the F-15 throttle used to initiate AAI interrogations. Due to radar scan pattern, it is possible that an F-15 interrogation attempt might not be successful because the radar antenna sweep pattern (during the period of the interrogation) does not highlight the interrogated aircraft.

Flight tests were flown at Nellis AFB with one or two F-15Cs interrogating two Air Force MH-60s flying in close proximity (less than 1000 feet apart). The results of those flights indicated the F-15 had a high success rate interrogating the MH-60s in Mode IV. The unsuccessful interrogations were explained by intermittent test conditions such as terrain masking and the absence of a radar lock-on (correlation). (Atch 5)


JEFFREY M. SNYDER, Maj, USAF
F-15 Maintenance Board Member


5 Atchs

1. Statement of Certification
2. Memo from MDA, 9 May 94
3. Memo from Mr Grafton, undated
4. Test results - TACCSF (see classified addendum)
5. Ltr from 57 TESTG/CC, declassified (see classified addendum for complete document)

STATEMENT OF CERTIFICATION

I am Major Jeff Snyder, assigned to the 48th Fighter Wing, RAF Lakenheath England as the squadron maintenance officer, 493rd Fighter Squadron. I am the F-15 maintenance board member on the AFR 110-14 Accident Board, investigating the crash of two US Army Black Hawk helicopters and the possible involvement of US fighter aircraft in the crash of these helicopters in the northern No-Fly Zone of Iraq on 14 Apr 94. I have held various positions as a F106 and F-15 maintenance officer, squadron commander, and logistics staff officer over the past 15 years. I have been a maintenance training squadron commander and equipment maintenance squadron commander. I served as Research Fellow at RAND Corporation and as Chief, Maintenance Plans and Policy Branch at HQ United States Air Forces in Europe. I received my Master's Degree in Logistics Management from the Air Force Institute of Technology. I have been associated with the F-15 since 1983.

Date: 5/16/94


JEFFREY M. SNYDER, Major, USAF
F-15 Maintenance Board Member

VIA

DATE: 09 MAY 1994

ADDRESSEES, CARBON COPIES:

TO: Mr. J. Mobley (LFEFF)
296 Cochran St.
Robins AFB, GA 31098-1622

IC: D. Buechler, C. Murrell, P. Nelson, S. Winkler

D D T S	ENCLOSURES & NO. OF COPIES									
	1	2	3	4	5	6	7	8	9	10
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1	1									

E N C L N O.	R E F N O.	T Y P E O F D A T A	N U M B E R	R E V	D E S C R I P T I O N	C L A S S	S E N T F O R			
							A P P R V	C O E M N T	I N F O	
1					MDA-E Response to F-15 IFF Questions 09 May 1994	U				X
	a	WRALC FAX	05 May 94		Jerry Kelly (WRALC) fax concerning F-15 IFF questions related to the F-15/Blackhawk incident					
	b	WRALC FAX	09 May 94		Jerry Mobley (WRALC) fax concerning F-15 IFF questions related to the F-15/Blackhawk incident.					

1. Enclosure (1) is provided for information in accordance with your request.
2. Please do not hesitate to contact Don Buechler at (314) 233-7605 if you have any other questions concerning this subject.

S.L. Winkler
S.L. Winkler
Team Leader
F-15 CNI Controls and Recorders
D3106 B34/MC 03431 10/(314) 233-0915

MDA-E Response to F-15 IFF
Questions
09 May 1994

The following information is provided to answer the questions included in Reference (b).

1. From the Reference (b) information MDA received, we assumed the following:

AAI Operation

Master mode - AUTO
Code switch - 4A or 4B
S1, S2 switches - 0, 3
Code switches - N/A

Radar - STT

2. - When the AAI is in AUTO Master Mode (S1, S2 set as above) and the Radar in STT the following occurs:

When the Interrogate switch is depressed, the AAI will interrogate for 116 milliseconds in each of the following modes 4, 1, 2, 3.

- a. If no DETECT or IDENT is sent to the radar by the AAI, the radar will cycle the INHIBIT BIT and interrogations will continue (1 cycle per second) as long as the interrogate switch is depressed.
 - b. If a DETECT or IDENT is sent to the radar by the AAI, interrogations will cease, but the symbol (circle or diamond) should remain displayed until the Interrogate switch is released or the radar breaks lock.
3. Replies to "Questions to MDA" -
 - a. If the fighter had a circle displayed, and the Interrogate switch was not released, the circle should have remained until the Interrogate switch was released.
 - b. Why did the circle disappear and no replies received on subsequent interrogations?
"Beats me"
 - c. Can the situation be replicated in the lab? Not completely, it is impossible to duplicate all the real life variables such as: transponder antenna patterns of the helicopters, effects of the helicopter rotors on the IFF signals, and multipath effects.

MDA-E Response to F-15 IFF
Questions
09 May 1994

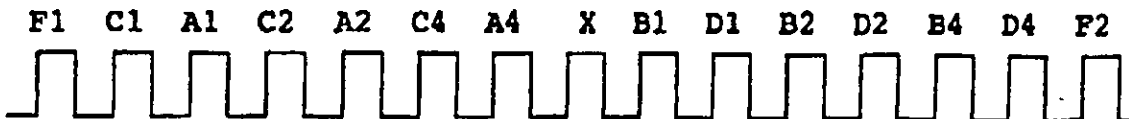
The following information is provided to answer question 3 included in Reference (a).

Question 3. Is MDA aware of any research or any problems with interrogating two targets in close proximity to one another (within one mile apart)?

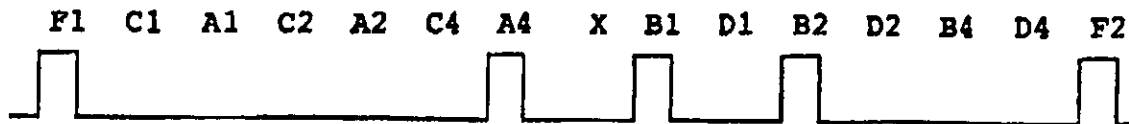
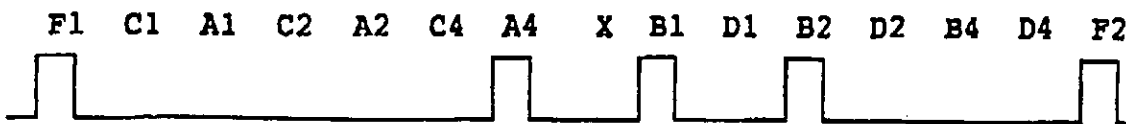
Answer: A condition known as garbling can exist when replies are generated from two targets in close proximity to one another. Garbled replies are replies which overlap so that pulses of one reply occurs in an unused pulse time frame of the other reply, thereby corrupting the code. This condition is not F-15 unique. This condition has the most affect on SIF Correct Code operations where neither reply is decoded. The code pulses of the replies are spaced in increments of 1.45 microseconds from the first F1 pulse. The reply pulse position tolerance is ± 0.10 microseconds, so if the delay changes by 0.10 microseconds (increase or decrease) the interrogating system should correctly decode the replies.

Example:

Reply pulse position:



Two replies, each with a code of 43 in Mode 1.



Result of combined replies:



VIA

DATE: 06 MAY 1994

ADDRESSEES, CARBON COPIES

ENCLOSURES & NO. OF COPIES

TO: Mr. J. Kelly (LFEFF)
296 Cochran St.
Robins AFB, GA 31098-1622

D D T S	ENCLOSURES & NO. OF COPIES									
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1	1									
1	1									

IC: D. Buechler, C. Murrell, P. Nelson, S. Winkler

E N C L N O.	R E F. N O.	T Y P E O F D A T A	N U M B E R	R E V	D E S C R I P T I O N	C L A S S	S E N T F O R		
							A P P R V	C O E M N T	I N F O
1	a	WRALC FAX	5 07 May 94		MDA-E Response to F-15 IFF Questions 06 May 1994 Jerry Kelly (WRALC) fax concerning F-15 IFF questions related to the F-15/ Blackhawk incident	U			X

1. Enclosure (1) is provided for information in accordance with your request.
2. Please do not hesitate to contact Don Buechler at (314) 233-7605 if you have any other questions concerning this subject.

S.L. Winkler
S.L. Winkler
Team Leader
F-15 CNI Controls and Recorders
D310B/B34/MC 0343110/(314) 234-0915

MDA-E Response to F-15 IFF
Questions
06 May 1994

The following information is provided to answer the questions included in Reference (a).

Question 1. Are there any anomalies of the AAI system that could result in false targets during an AAI interrogation? In mode 1 or mode 4?

Answer: If the system is installed correctly and working properly, there should be no false targets.

Question 2. Does MDA have any info on false returns associated with AAI interrogations with simultaneous IBS BIT lights?

Answer: Assuming that the question is interpreted to mean that the IBS is inoperative (no blanking provided) and that the Transponder is replying to AAI interrogations. In this situation there would be no false returns for ranges of concern, there possibly could be a response that would appear near zero range at the bottom of the VSD display.

The answer to question 3. will be provide later.


Engineering Report
Close Proximity IFF Targets

DoD AIMS Program Office

Question: Is the DoD AIMS Program Office aware of any problems associated with interrogating aircraft flying in close proximity of each other?

It is the expert opinion of the undersigned engineer, that it is feasible for aircraft flying in formation (with both transponders on) to interfere with each other and prevent either one from being identified by an interrogating aircraft. In some scenarios both could be identified. However, with all systems working properly the most common occurrence is that one will be identified and the other rejected.

This could happen in all modes (Modes 1, 2, 3/A or 4), but because of the pulse spacing and decoder operation of the Mode 4 reply, it would be more prevalent in Mode 4 operation.


Travis B. Grafton
ATTI Contractor
DoD AIMS Program Office

I, Travis B. Grafton have been associated with the Mark X/XII system since 1962. I have installed the equipment in ATC facilities. From 1980 to 1987 I was the DoD AIMS Program Engineer having the responsibility for the overall integrity of the Mark XII system. I retired in 1987 from civil service and in 1993 returned to the AIMS Program Office, providing contractor engineering support.

ATTACHMENT 4 IS IN CLASSIFIED

ADDENDUM TO REPORT

~~CONFIDENTIAL~~



DEPARTMENT OF THE AIR FORCE
87TH TEST GROUP (ACC)
NELLIS AIR FORCE BASE NEVADA

MEMORANDUM FOR Colonel Fain
USAF Investigating Officer
Incirlik AB, Turkey

FROM: 57 TESTG/CC

SUBJECT: F-15 Mode 4 Test

1. (U) Test missions were conducted on 10/11 May. The first day consisted of 2 F-15C's and 2 HH-60G "Pave Hawk" helicopters and the second mission using 1 F-15C and 2 "Pave Hawks". The purpose of this test was to evaluate Mode 1/2/4 replies.

[Classified material deleted (145 words)]

3. (U) These profiles were flown using F-15C's (APG 63/70 radar, CAN radar tape, S₁, S₂ of O.3) The HH-60G "Pave Hawk" was configured using the APX-100 IFF system. Nine runs were accomplished, 2 high altitude, and 7 low altitude consisting of 100 interrogations. During the first high altitude run we were able to accomplish interrogations with the helicopters in a four by one mile wide canyon approximately 1000 feet deep.

[Classified material deleted (46 words)]

Ted J. Carter
TED J. CARTER, Colonel, USAF
Commander

CERTIFICATE OF DECLASSIFICATION	
I certify that the information contained in this document has been declassified from	
CONFIDENTIAL	to UNCLASSIFIED.
19 May 94	<i>Donald G. Norris</i>
Date	DONALD G. NORRIS, GS45, DAC Declassification Team Chief, HQ USEUCOM

TAB O

ADDITIONAL SUBSTANTIATING DATA REPORTS

	O-1
	O-2
O-1 UH-60 Black Hawk 88-26060	O-3
O-2 UH-60 Black Hawk 87-26000	O-4
O-3 E-3B AWACS	O-5
O-4 F-15C 79-0025	O-6
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O-6 Human Factors	O-8
O-7 Medical Reports	O-9
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O-11 Technical Report UH-60 Black Hawk IFF/AAI Systems	

TECHNICAL REPORT

UH-60 BLACK HAWK IDENTIFICATION-FRIEND-OR-FOE (IFF) SYSTEM

Aircraft Evaluated: UH-60 Black Hawks, Serial Numbers 88-26060 and 87-26000
Incident Date: 14 April 1994

I. INTRODUCTION: The purpose of this evaluation was to examine potential reasons which could have resulted in unsuccessful Mode IV interrogations of the Identification-Friend-or-Foe (IFF) systems on the UH-60 Black Hawk aircraft, serial numbers 88-26060 and 87-26000.

II. BACKGROUND: This technical report was prepared for the official AFR 110-14 aircraft accident investigation into the facts and circumstances surrounding the crash of two US Army UH-60 Black Hawk helicopters (Eagle Flight) and the possible involvement of US fighter aircraft in the crash of these helicopters in the northern No-Fly Zone of Iraq on 14 April 1994. Aircraft 88-26060 arrived at Diyarbakir AB, Turkey on 14 June 1993, and had a total of 1222.0 flight hours on the airframe prior to the last mission. Aircraft 87-26000 arrived at Diyarbakir AB, Turkey on 14 June 1993, and had a total of 1247.3 flight hours on the airframe prior to the last mission.

The assessment of the UH-60 Black Hawk's Mode IV capabilities and irregularities, if any, was conducted in an effort to account for inconsistencies in the available evidence related to the functionality of the Black Hawks IFF Mode IV. Specifically, the testimony of one of the F-15 pilots indicated that he interrogated Mode IV, and received one "friendly" response, followed by two negative responses. (TAB AC36/para2) The second F-15 pilot indicated he received only a negative response. (TAB V28/Q90-91)

Mode I and Mode II interrogation returns were observed by AWACS, but no evidence was found to indicate that AWACS controllers attempted a Mode IV interrogation of the UH-60 Black Hawk helicopters transponders. Analysis of one Black Hawk transponder (87-26000) showed indications that Mode IV was on and that the IFF caution light was not on. (TAB O1b; O2b) Tear down analysis of the second transponder (88-26060) has not been completed. (TAB J1e)

Given these inconsistencies in the evidence, it was appropriate to conduct an analysis of the potential reasons for unsuccessful Mode IV interrogations of the UH-60 Black Hawk transponders by the F-15s.

III. EVALUATION:

This evaluation was conducted by reviewing applicable technical manuals and publications and by consulting experts in the field of IFF systems operations. Possible scenarios which could explain a failure to respond to a presumptively proper F-15 IFF interrogation were developed and analyzed.

The general serviceability and mechanical condition of the transponders and the cryptographic computers was evaluated in separate technical reports (TABs O1b; O2b) and is not included in this assessment. Where appropriate, the results of the tear down analysis conducted on the aircraft IFF system components is incorporated into this evaluation.

Specific maintenance procedures with possible relevance to the mishap were investigated. The Eagle Flight Detachment policies and procedures for loading Mode IV codes into the aircraft and for operationally checking the validity of those codes were reviewed. The Detachment's adherence to Department of the Army maintenance policies and procedures was also evaluated.

IV. DETERMINATION:

A. BACKGROUND.

The IFF system consists of the AN/APX-100 (Transponder), the KIT 1C (Cryptographic Computer), and two omnidirectional antennas, one installed on the top fairing between engine exhaust ports (top center of the aircraft, behind the rotor blade mast), and one on the lower fuselage in the center portion of the aircraft, under the transmission section. (TAB AA20/p3-63, para3-158)

The AN/APX-100 transponder set is designed to provide automatic radar identification of an aircraft to all suitably equipped challenging aircraft and surface or ground facilities within the operational range of the system, provided a compatible code is entered into the interrogation system and into the transponding system. (TAB AA20/p3-63, para3-157) The system receives, decodes and responds to interrogations of operational Mode I, II, IIIA, IIIC and IV codes. The AN/APX-100 can transmit specially coded identification of position and emergency signals to interrogating stations, if conditions warrant. (TAB AA20/p3-63, para3-157)

There are five independent coding modes available to the operator. The first three are non-secure and may be used independently or in combination: Mode I provides 32

possible code combinations and is a method for an interrogating system to track military aircraft or ships. Mode II provides 4096 possible code combinations to the interrogator; it is used to track a specific aircraft. Mode III/A provides a geographic identification of military and civilian aircraft positions to an interrogating station. Mode III/C indicates pressure altitude, to the nearest 100 ft increment, of the military or civilian aircraft being interrogated. (TAB AA20/p3-63, para3-157) Mode IV is an encrypted, secure mode that transmits a coded pulse to an interrogating system to identify a friendly aircraft. A compatible code for the operational time period must be loaded into the interrogating system's KIR 1C and the transponding system's KIT 1C for the interrogator to receive a friendly indication. (TAB AA21/p2-3, para2-4.2, p4-8, para4-6.1)

The AN/APX-100 transponder provides two indications to assist the aircraft operator in evaluating the effectiveness of the transponder's response to an interrogating signal. The "reply light" on the transponder will illuminate if a compatible code has been received and a response is being transmitted; there is also an audio tone in the operator's head set to indicate that the transponder system has been interrogated by an incompatible Mode IV code. In addition, the aircraft Master Caution light will illuminate, along with a specific Mode IV segment light on the caution advisory warning panel, to alert the crew if the transponder has not replied to the Mode IV interrogation. (TAB AA21/p4-7, para4-5.1.5, p4-8, para4-5.2.1)

The current Mode IV code must be loaded into the transponder prior to each mission. The Mode IV codes for each day of any given month are imprinted on paper tape. There is an individual tape segment for each day of the month. The first step in loading the Mode IV code into the transponder is to load the specific code for the day into the KYK-13 (Electronic Transfer Device). The KYK-13 is loaded by connecting a KOI-18 (Tape Reader) to the KYK-13, inserting the coded paper tape, and running the tape through the KOI-18. The loaded KYK-13 is then disconnected. (TAB AA21/p4-21, para4-16.3)

The KYK-13 is connected (with a plug-on data transfer cable) to the KIT 1C (Cryptographic Computer) in the aircraft. When the proper switch on the KYK-13 is turned to the load position, the code is passed from the KYK-13 to the KIT 1C and is loaded and available for access by the transponder. If the KIT 1C is not loaded properly, the aircraft Master Caution light will illuminate, along with a specific Mode IV segment light on the caution advisory warning panel, to alert the crew that the transponder has not accepted the code. (TAB V60/p3, para4)

It is possible to load the codes for two consecutive days into the KIT 1C. If pending operational requirements will make it impossible to reload the Mode IV code prior to the beginning of the next day, two days of codes would be loaded. At the end of the first day,

the next day's Mode IV code may be selected by using the code A/B switch on the transponder. Failure to change to the new day's code at the end of the first day will make the system's Mode IV code incompatible with other Mode IV systems during the second day. (TAB AA21/p4-9, para4-6.3)

The internal aircraft checks will only indicate whether a valid code has been properly loaded, not whether the loaded code is the proper code of the day.

B. ANALYSIS OF POTENTIAL IFF SYSTEM PROBLEMS

Keying Mode IV into the IFF system prior to flight. Mode IV codes are issued by a Communications Security Custodian for a one-month period. For the month of April 1994, the codes used by Eagle Flight Detachment were the proper edition of the Mode IV codes. (TAB V121/p1, para4) (Atch 3)

Loading the Mode IV code into the transponder requires the Eagle Flight Detachment operations NCO to obtain the daily codes from the Pirinclik AB, Turkey, Communications Center. This was accomplished on 31 March 1994, when the Eagle Flight NCOIC went to the Communications Center where he signed for and received the canister containing the daily codes for the calendar month of April 1994. (TAB V121/p2, para4) The canister and daily codes were secured in the Eagle Flight operations office safe. (TAB V121/p1, para4)

The night before the 14 April helicopter mission, the Detachment NCOIC removed the code for the next day from the safe and loaded it into the KYK-13 (Electronic Transfer Device). (TAB V58/p3, para1) The KYK-13 was stored in the secure container overnight, then signed out on the morning of the scheduled flight by the chalk one (lead) pilot. There is no evidence as to show whether the pilot transferred the KYK-13 to the crew chief. (TAB V58/p3, para1)

The crew chief normally keys the KIT 1C for Mode IV prior to mission take-off from Diyarbakir AB. In the past, the civilian contract maintenance personnel have been called on to assist a crew chief with the loading of the KIT 1C. The civilian maintenance personnel have more experience with the equipment used at Diyarbakir AB, than do the military crew chiefs who rotate into the unit at irregular intervals. The civilian maintenance personnel testified that they had encountered no avionics discrepancies that they could not properly repair. (TAB V61/p1) (For a listing of transponder maintenance writeups, see TABs O1b and O2b.)

When the crew chief has a problem with the loading process, the civilian maintenance personnel are available to load the KIT 1C. (TAB V61/p1, para4) After the KIT 1Cs are loaded and the mission departs, the KYK-13 is retained at the flight line. (TAB V58/p3, para1)

There are several ways that the loading procedure could be done improperly. The code provided by the Communications Center could be incorrect; the information could be passed incorrectly to the KYK-13, as a result of a malfunction of the KYK-13 or KOI-18; or the KIT 1C could malfunction and not receive the "fill." There is no evidence to indicate that any of these problems occurred during the preparations for the mission on 14 April 1994.

There is evidence that Eagle Flight loaded the KYK-13 with the proper Mode IV code for 14 April 1994. On 15 April 1994, the Pirinlik AB Communications Center COMSEC alternate manager (the individual who issued the codes to Eagle Flight's NCOIC) went to the Detachment's operations office and verified visually that the unit had used the proper code for 14 April 1994. He personally verified the prior destruction of the code for 13 April 1994, and observed that the code for 15 April 1994 was present in the canister. (TAB V121/p3, para1)

The COMSEC alternate manager also noted that he had personally issued the codes each month the two months prior to April, and for the month of May 1994. He testified that he had never heard of any problem being encountered with codes he issued, and he has never been told that a code he issued had been found to be incompatible. (TAB V121/p3, para2)

There is also evidence that the loading process was accomplished properly. The NCOIC testified that he loaded the KYK-13 the night of 13 April, and signed the KYK-13 over to the pilot of chalk one (lead) the next morning. (TAB V58/p3, para1) On 14 April, the crew chiefs were observed opening the avionics compartment doors (hoods) of the helicopters, which is where the KIT 1Cs are located. The military personnel did not request the assistance of the civilian contract personnel in loading the KIT 1Cs. (TAB V61/p1, para 4) If the KIT 1C had not been loaded properly, a cockpit light should have illuminated, notifying the crew that there was a problem with Mode IV. (TAB V60/p3, para4)

The crew chief who loaded the KIT 1C was killed in the crash. On 28 April 1994, the other Eagle Flight crew chiefs were evaluated on the performance of keying procedures for the KIT 1C. Operations personnel provided a correctly loaded KYK-13. Each crew

chief performed the Mode IV keying procedure in accordance with the applicable technical manuals. (Atch 4)

Analysis of the two KYK-13s from Eagle Flight was accomplished by Tobyhanna Army Depot, Tobyhanna Pennsylvania. The two KYK-13 electronic transfer devices were found to be functioning properly. (TAB J1g)

The available evidence indicates that the IFF transponder keying of 88-26060 and 87-26000 on 14 April was accomplished with the correct code for the day and that the loading procedures were accomplished in accordance with applicable directives and technical manuals.

Operational check of Mode IV prior to flight. Pilots are required to check the operation of the transponder system including the Mode IV, as part of their run-up checklist, and a cockpit test of the system will show if the Mode IV has been keyed and if the system has retained the code. The unit SOP states that all IFF systems must be on and operational prior to and throughout the mission. (TAB AA11/p2, app c3)

Eagle Flight Detachment military and civilian maintenance personnel were interviewed. Testimony indicates that the Mode IV in-cockpit self test was done before every mission take-off from Diyarbakir. If that check was not positive, the aircraft would not be allowed to fly. (TAB V60/p3, para4)

There was no external testing equipment at Diyarbakir to check the operation of the transponder. (TAB V60/p3, para3) The Mode IV external check was normally done by contacting AWACS after take-off from Diyarbakir and requesting interrogation and verification of Mode IV function. In the Detachment, it was common practice to request a Mode IV interrogation more often than the 25 flying-hour scheduled check. (TAB V49/p2, para3-4) The Mode IV on aircraft 88-26060 was last checked on 13 April 1994. (TAB V51/p2, para5) The Mode IV on 87-26000 was last checked on 6 April 1994. (TAB H2b) Both Mode IV checks were successful. There was no evidence of a Mode IV check of the aircraft by AWACS on 14 April 1994. (TAB O3f)

Shut-down procedures during enroute stops. The Eagle Flight mission on 14 April 1994 included a stop for passengers at Zakhu, Iraq. Post-landing procedures are specified in Army Technical Manuals (TAB AC29/pp8-15, 8-17). Avionics (including the transponder) shut-down procedures normally begin prior to power being removed from the aircraft. The Mode IV code switch must be moved to the "Hold" position and then released. Electrical power is then turned off. If the Mode IV code switch is not moved to the "Hold" position prior to turning off electrical power, the transponder loses the Mode

IV code from its memory. (TAB AC29/p3-66) A diagram of the AN/APX-100 transponder is attached for reference. (Atch 5)

The unit standard was to accomplish all tasks "by the checklist." This fact was brought out by testimony. (TAB J2b/p1, para 2; V50A/Q59) When asked to consider the history of the Detachment's performance of the Eagle Flight mission, the remaining pilots could recall only two to three occasions where a single aircraft lost its Mode IV code as a result of not moving the code Hold switch to the "Hold" position prior to removing electrical power. No pilot could recall a situation where both aircraft lost their Mode IV codes. (TAB V103/p9, para2-3; V48/p13-14)

Detachment pilots testified that if their aircraft lost the Mode IV Code, they would call and advise AWACS of the problem prior to departing to continue the mission. (TAB V103/p9, para1-3; V48/p14, para1) There is no evidence that AWACS received such a communication from Eagle Flight on 14 April.

Mode IV code turned off during flight. The testimony of the remaining Eagle Flight pilots established that the practice in the Detachment was to fly with Mode IV on and squawking the code at all times. (TAB V49/p2, para4; V50A/Q47-50, Q67-68; V51/p3, para1; V103/p10, para2-4) An aircraft would be rejected for a mission if the transponder was inoperable. (TAB V48/p7, para4)

There is some evidence that Eagle Flight pilots were concerned about receiving IFF caution lights (indicating their aircraft was being interrogated). (TAB V33/Q261, Q272-274) The frequency of the "lock-ons" and the corresponding concern for the safety of their aircraft and personnel was passed on to the CTF headquarters. (TAB V103/p14, para3-5) There is no evidence that this concern caused any Eagle Flight pilot to turn off the Mode IV during flight.

An indication concerning the operational status of the Eagle Flight Mode IV function is contained in the testimony of the F-15 flight lead. He reported he had received a Mode IV friendly response on his initial interrogation attempt, but had received no response on subsequent attempts in radar search and in radar single target track. (TAB AC5b) The pilot further indicated that he thought the initial friendly response was consistent with a known AAI anomaly. (TAB V26/Q35) However, the Board could find no evidence to support the existence of such an anomaly.

Except as noted below, if the UH-60 Black Hawk's transponder Mode IV switches were turned off during flight, an interrogation of Mode IV by an F-15's Air-to Air IFF system would result in illumination of the Mode IV caution light. (TAB AA21/p4-8, para5-4.2.1)

However, the tear down analysis conducted by the Naval Air Warfare Center, Indianapolis, Indiana, on the transponder taken from the wreckage of aircraft 87-26000, revealed that at the time of the incident, the IFF caution light circuits were in positions which were not consistent with illumination of the IFF caution light. (TAB J2e/p1)

The tear down analysis notes that the electrical circuits would have been in different positions if there had been an incompatible code interrogation, or a mechanical failure within the system. (TAB J2e/p1) If the code is lost or the transponder experiences a hardware failure, the system cannot be started again in flight. The code will remain lost until a new code is entered into the KIT 1C, or until the transponder is repaired by maintenance personnel. Eagle Flight could not have reloaded a lost Mode IV code during the mission, because the KYK-13's with the codes were secured on the flight line at Diyarbakir AB. (TAB V58/p3, para1) There is no evidence that Eagle Flight stopped enroute to perform transponder maintenance.

There are four switches which could be used to turn off, or change the operation of the Mode IV function. (see, Atch 5 (transponder diagram)) These comprise the transponder master switch, and three Mode IV function switches, the A-B-zero-hold switch, the test-on-out switch and the audio-light-out.

The tear down analysis could not determine the position of the audio-light-out switch on aircraft 87-26000's Mode IV control. The audio-light-out switch is discussed first, because the operational setting of that switch may have affected the functioning of the Mode IV and the IFF caution lights during the mission on 14 April. The functioning of the remaining transponder switches follows discussion of the audio-light-out switch.

The audio-light-out switch has switch positions which enable or disable various Mode IV caution functions. In the audio position, the Mode IV reply light and Mode IV audio tone are enabled. In the light position, the Mode IV reply light is enabled and the Mode IV audio tone is disabled. In the out position, both the Mode IV reply light and Mode IV audio tone are disabled. The press-to-test function of the Mode IV reply light is also disabled. (TAB AA21/p4-7, para4-5.1.4)

Investigation by Naval Air Warfare Center engineers indicated that the "out" switch position may also prevent Mode IV cautions. (TAB J2e/p3, para3) The technical manuals concerning operation of the audio-light-out switch state that only the Mode IV reply light and Mode IV audio tone are disabled. (TAB AA21/p4-7, para4-5.1.4)

If it is assumed that the IFF caution light is also disabled when this switch is moved to the out position, the caution light would have been prevented from illuminating, even if presented with an incompatible code interrogation or a hardware failure.

Testimony of the remaining Eagle Flight pilots established that the practice in the Detachment was to fly with Mode IV on and squawking the code at all times, and that the pilots relied on the transponder caution functions to warn them of potential problems. (TAB V49/p2, para4; V50A/Q47-50, Q67-68; V51/p3, para1; V103/p10, para2-4) Disabling the caution functions would have eliminated the pilot's ability to know when the transponder has failed or the aircraft has been interrogated by an incompatible code.

In addition, the OPC ACO required all aircraft operating in the TAOR to squawk Mode IV. (TAB AA0/Vol.2, para3o) Evidence indicates that, following an independent Air crew Training and Aircraft Maintenance Inspection conducted from 29 March to 5 April 1994, the Detachment Commander (flight lead) and other members of the Detachment were commended for their "...highly professional and safe mission accomplishment." (Atch 6) Disabling the IFF caution systems would be inconsistent with the assessment of the unit's approach to the conduct of a safe mission. The evidence suggests that it is unlikely that four Eagle Flight pilots would have disabled their Mode IV caution functions, thereby disabling the IFF caution light in a non-illuminated position.

Assuming that the audio-light-out switch was not in the "out" position, and that the console IFF caution light was not disabled with that switch in the "out" position, the functioning and switch settings of the remaining transponder switches must also be examined.

The transponder master on-off switch has switch positions for on, off, standby (for use during warm-up, or while on the ground), and emergency. If the master on-off switch is turned to the off or standby positions, no Mode codes are transmitted, and no interrogations received. However, even if the master on-off switch is in the off position, the console IFF caution light will be illuminated. The IFF caution light will also be illuminated if the transponder has a hardware failure. (TAB AA30/p7, para4) If the master on-off switch is in the emergency position, the aircraft transmits a special code received on Modes I, II, and IIIA by all other monitoring aircraft, to include the AWACS. (TAB AA20/p3-65, para3-160)

The evidence demonstrates that the Eagle Flight aircraft transponders were squawking on Modes I and II codes. (TAB Z4) Except as noted above, this indicates that the master on-off switch was not in the off or standby positions. In addition, there is no evidence that the emergency code was being transmitted by Eagle Flight aircraft, which indicates that

the master on-off switch was not in the emergency position. The evidence indicates that the transponder master on-off switch was turned to the on position, and that power was being supplied to the transponders at the time of the incident. (TAB AA20, p3-63, para3-157)

The transponder Mode IV function is controlled by three switches, including the audio-light-out switch discussed above. (see, Atch 5 (transponder diagram)) The first switch includes positions for A, B, Zero, and Hold. The A and B positions select the code for a particular day from among two loaded codes. This switch cannot be used to turn off the Mode IV function. The Zero switch setting on the transponder causes the loss of the Mode IV code from the KIT 1C (Cryptographic computer). (TAB AA21/4-9, para4-6.3, 4-7)

The Hold switch setting is spring-loaded to return the switch to the A or B position and is used to hold the Mode IV code in the transponder during enroute shut downs. (TAB AA21/p4-5, para4-5.1.1) The switch setting cannot be used to turn off the Mode IV function. If the switch is turned to the wrong position for that particular day, the IFF caution and master caution lights will illuminate for 2.5 seconds when the aircraft is interrogated with the correct code. (TAB AA21/p4-8, para4-5.2.1a)

The tear down analysis of the electrical circuits revealed that the IFF caution light and master caution light were not on at the time of the incident. Except as noted above, this indicates that either the system did not receive any interrogation with an incompatible code; or it received an interrogation, and the codes set in the interrogator's and Black Hawk's transponders were compatible.

Engaging the Zero switch setting will also result in the illumination of the IFF caution light. (TAB AA21/p4-5, para4-5.1.1) The system cannot be reset (to extinguish the IFF caution light) without either reloading the code or performing maintenance on the component. Except as discussed above, the evidence indicates Zero switch setting had not been used and the Mode IV code had not been lost at the time of the crash. (TAB AA21/p4-8, para4-5.2.1a)

The final switch has positions for test, on, and out. The "test" setting of the test-on-out switch is spring-loaded to return to the on position following the self test, and cannot be left in the test position, if functioning correctly. The "out" setting can be used to separately turn off the Mode IV function. When the "out" switch setting is engaged, the Mode IV caution light is illuminated. (TAB AA21/p4-5, para4-5.1.3) As noted above, the available evidence indicates the IFF caution light was not on at the time of the incident and there is no evidence that Eagle Flight could have reloaded the Mode IV code or

performed maintenance on the transponder during the mission. Accordingly, it is unlikely the "out" switch setting had been used at the time of the crash.

The capability of the IFF system to send a response through the IFF antenna and wiring system was also examined. The UH-60 Black Hawk uses essentially the same wiring and antennas to transmit responses to both Mode II and Mode IV interrogations. (TAB AA30/p8, para3) There is evidence that both UH-60 helicopters were transmitting the proper Mode II code. (TAB Z4) Accordingly, the evidence indicates that its likely that the antenna systems were functional and were capable of transmitting a response from any IFF Mode, including Mode IV.

As discussed earlier, there is no evidence that the Mode IV code loading procedures were defective. There is no evidence to indicate that the UH-60 Black Hawk pilots deliberately turned off the Mode IV code on both helicopters while in flight. The available evidence suggests that the transponder Master switch and Mode IV switches were in the on positions and that aircraft 87-26000 was transmitting a Mode IV code. Analysis of the functional capability of aircraft 88-26060's transponder cannot be accomplished until the results of the tear down analysis are received.

Line of sight interrogation/response. The AAI interrogation and response system is "line of sight" dependent. Either the AAI interrogation or the reply from an aircraft transponder can be blocked by atmospheric conditions, objects or terrain which interfere with the path of the signal. (Atch 7)

The terrain along the flight path of the UH-60 Black Hawks is highlighted by mountains, steep hills, and narrow valleys. (TAB R1) When operating in the TAOR in support of the MCC, Eagle Flight routinely flew at a tactical level, generally staying below ridge lines to avoid detection. (TAB V100/Q20; V100A/Q16,18)

The terrain in the area of the incident, coupled with the low altitude flight profile of the UH-60 Black Hawks, provides some evidence that "terrain masking" may have prevented a successful reply to any interrogation by the F-15s.

Effect of helicopter low level flight profile on the correlation between the F-15 fire control radar and AAI interrogator. The interrogator line of sight is controlled by the fire control radar (FCR) which must point the interrogator main beam at the target being queried. The fire control radar (FCR) used on the F-15Cs involved in the incident was the AN/APG-63. It is a multimode pulse doppler radar designed primarily for engaging high speed (i.e., narrow doppler spread) targets.

In this aircraft, the AN/APX-76 interrogator system is slaved to the FCR line of sight. The FCR uses the target doppler to track the target and point the interrogator. (Atch 8, para2) Aside from the potential loss of line of sight due to obstruction caused by the mountainous terrain and relative low level of the targets, failure of the fire control radar to achieve and maintain a solid lock on the target aircraft could also have resulted in a failure of the AAI to display a IFF response from an interrogated transponder. (Atch 8, para1)

Testimony of one of the F-15C pilots indicated that at the range of the first interrogation of the Black Hawks, the FCR system was indicating a negative altitude for the helicopters. This is an indicator of an unstable radar lock (TAB V26/Q35)

For slow moving, low altitude rotary wing targets, the doppler signature is dominated by rotor doppler of the helicopter, not the body doppler caused by the aircraft motion. Moreover, when tracking targets close to the terrain, the FCR main beam will also pick up a doppler return from the terrain. The terrain doppler return results from the relative motion of the ground to the speed of the F-15, creating doppler clutter from which the FCR must pick out the slow moving helicopter. (Atch 8, para 2)

The AN/APG-63 can have difficulty locking on to slow moving targets flying at low altitudes. The problem is exacerbated by formation flight of the helicopters, because the rotors' doppler signatures tend to cancel in the center. The FCR computer will have difficulty identifying a single doppler target, which will result in a poor lock. (Atch 8, para 2)

The APX-76 incorporates a mode IV automatic evaluator which supplies mode IV reply information to the FCR computer. That information is correlated with the radar return of the target that the FCR and APX-76 believe sent the mode IV reply. If the response received from the transponder agrees with the position of the target displayed on the pilot's radar scope within the "correlation window," then an IFF reply is displayed on the radar scope at the radar targets position. Conversely, if the IFF return and the radar return do not match within the "correlation window," the APX-76 reply evaluator would present a no reply to the pilot (even though the transponder may have responded to an interrogation). (Atch 8, para3 & 4)

When the APX-76 receives a reply, it requests the FCR to verify that the reply was from that target. If the FCR had shifted to another target because it did not have a solid lock, it would declare that the reply did not come from the same "doppler target" it had interrogated. The APX-76 reply evaluator would present a no reply to the pilot. (Atch 8, para 4)

Interrogator side lobe suppression (ISLS). Each interrogation by an Air-to-Air Identification-Friend-or-Foe (IFF) Interrogation (AAI) system consists of a set of mode-identifying pulses. Pulses are transmitted from AAI systems in beams referred to as "lobes." The main lobe is the beam with the greatest signal strength. All other lobes are referred to as "side lobes" or "back lobes." To prevent transponders from replying to side lobe and back lobe interrogation, the AAI system inserts an ISLS pulse. (TAB AA21/p3-3, para3-5.5.2.1)

When a transponder receives an ISLS pulse equal to or of greater strength than the Mode identifying pulses, it will know it is a side lobe and the transponder will not reply. In areas where there are multiple interrogations occurring, the ISLS pulse reduces "clutter" on the interrogator's screen by eliminating side and back lobe responses. The ISLS pulse also prevents or reduces the chance that replies on the main interrogating beam from distant contacts would be inhibited, and consequently not be processed by the interrogator's processor. (TAB AA21/p3-3, para 3-5.5.2.2)

If the radar lock by the lead F-15C was made when his wingman was in a position offset to the side (90 degrees abeam), it is possible the wingman's IFF transponder signal was processed through the side lobe of the lead F-15's interrogation receiver evaluator. If this occurs, the wingman's signal would be stronger and could cancel out any signal reply from the UH-60 as well as the wingman's signal.

In addition, if the radar lock by the F-15 was done at an offset to the direction of the fire control radar antenna of the fighter, it is possible that the UH-60 Black Hawk transponder's response would have been prevented by ISLS, due to the fact that the main beam of the interrogator is in the direction that the fire control radar antenna is pointing. This would cause the Black Hawk to be interrogated by the side lobes of the interrogator, thereby causing the ISLS pulse to process a nonresponse by the transponder. There is no evidence available to determine whether the F-15 AAI interrogation (including the ISLS pulse) prevented the UH-60 Black Hawk transponders from responding. The interrogator side lobe suppression may have been related to the accident.

The potential effect of ISLS may also be exacerbated by the fact that the F-15 AAI receiver incorporates a Receiver Side Lobe Suppression (RSLS) function. RSLS is an interrogator system function that tests transponder replies to ensure they originated from the antenna's main beam. Two receive channels are used. One receives its replies from the "sum" or directional channel and the other through the "difference" or omni channel. The interrogator compares the level of the two channels. The "sum" or directional channel must produce the larger signal for the reply to be accepted. (TAB AA21/p5, Glossary)


There is no evidence available to determine whether the RSLS function may have prevented acceptance of a UH-60 Black Hawk reply to an F-15 AAI interrogation. The receiver side lobe suppression may have been related to the accident.

Mode IV signal cancellation. Also considered was the possibility that two aircraft operating in close proximity might cancel out or otherwise affect the return response to an F-15 interrogation. The UH-60 Black Hawk aspect of this issue was referred to the Project Manager, Aviation Electronic Combat, 4300 Goodfellow Blvd., St. Louis, Missouri, who provided a preliminary analysis that indicated that he had no evidence to support the existence of such a cancellation problem. An independent input provided by the Naval Air Warfare Center, Aircraft Division at Indianapolis, IN. The Naval Air Warfare Center report indicated that the AAI interrogator should have seen, at a minimum one valid Mode IV response. (Atch 2)

The F-15C manufacturer, McDonnell Douglas Aircraft Corporation, and the DOD IFF Program Office confirmed the theoretical possibility of reply signals from two close proximity targets interfering with each other and preventing the interrogator from receiving either signal. A DOD IFF Program office representative indicated a more likely possibility was that the interrogating platform would only receive one of the two replies. (TAB O10/p2, para1)

Atch

- 1 Tear down Analysis Facilities
- 2 Interference Blanking Memorandum
- 3 COMSEC Material Report
- 4 Tech Adv Inspection
- 5 Transponder Diagram
- 6 Extract - Report of CASSD inspection
- 7 Extract - Line of Sight Propagation
- 8 Interrogator - Fire Control Radar memorandum
- 9 Tech Adv Qualifications


JOHN B. HALL
CW2, USA
Technical Advisor

14 May 94

MEMORANDUM FOR RECORD

SUBJECT: Teardown Analysis of UH-60 Black Hawk Components -- Facilities

1. Aircraft Survivability Equipment (ASE) and Avionics components recovered from the crash sites of US Army Black Hawks helicopters serial numbers 87-26000 and 88-26060 were forwarded for technical analysis
2. Components were forwarded to the Office of the Project Manager, Aviation Electronic Combat, ATTN: SFAE-AV-AEC, 4500 Goodfellow Blvd., St Louis, MO 63120-1798. That office forwarded components to appropriate laboratories for analysis as follows:
 - a. Arc 164. Navigational and Information Transmission Branch (WL/AAAI), Wright Laboratory, Wright Patterson AFB, Ohio, ACFT 87-26000 and 88-26060.
 - b. ICS C-6533. Navigational and Information Transmission Branch (WL/AAAI), Wright Laboratory, Wright Patterson AFB, Ohio, ACFT 87-26000 and 88-26060.
 - c. Kit 10. AFCSC CV, 230 Hall Blvd Ste 126, San Antonio, TX 78243-7075, Acft 88-26060.
 - d. Apr 55-V Digital processor. HQ. USAR, Com-Elec Cnd, Research Development and Engineering Center, NV & E Sensor Directorate, Ft. Monmouth, NJ 7703-5205, Acft 87-26000 and 88-26060.
 - e. APX-100. Naval Air Warfare Center, Aircraft Division, Indianapolis, IN, Acft 87-26000 and 88-26060.
 - f. AN/A1Q 144A. Robert W. Aamueller, Survivability Equipment Division, Ft. Monmouth, NJ 07703-5205, Acft 87-26000 and 88-26060.
 - g. AN Arc 186. Navigational and Information Transmission Branch (WL/AAAI), Wright Laboratory, Wright Patterson AFB, Ohio, ACFT 87-26000.
 - h. KY 58. US Army Depot, ATTN: SDSTO-MC, Tobyhanna, PA.
 - i. KY 58 control. US Army Depot, ATTN: SDSTO-MC, Tobyhanna, PA.



DOUGLAS C. SOUSA

CW4, USA

UH-60 Maintenance Test Pilot

Accident Investigation Board

MEMORANDUM

9 MAY 94

FROM: K.M. Pafford, PMA-20927
TO: COL. Thomas E. Reinkeber, 8FAE-AV-ADC


SUBJECT: CONFIRMATION OF TECHNICAL DATA PROVIDED DURING OUR TELECOM OF
9 MAY 1994

1. On 9 May 1994 the following question, from COL. Reinkeber, was posed concerning the operation of the AN/APX-100(V), in the context of overall system operation, i.e. the interrogator's interpretation of two simultaneous, valid MODE 4 responses:

If both AN/APX-100(V)s were on, and in MODE 4 at the time of the incident at issue and responding to mode 4 interrogations, would the interrogator, i.e. the APX-76, recognize valid MODE 4 responses?

Assuming that both systems (the interrogator and transponders) were fully operational and that both systems had the proper code of the day entered the interrogator should have seen, at a minimum, ONE VALID MODE 4 RESPONSE.

CC: PMA-209
NAWC 1012N



TOTAL P.02

**POST ACCIDENT INSPECTION
EAGLE FLIGHT DETACHMENT
AVIONICS OPERATION AND MAINTENANCE**

1 Detailed operational testing and operational evaluation was accomplished on aircraft survivability and communications equipment installed on 4 UH-60A Black Hawk utility helicopters assigned to Eagle Flight detachment located at Diyarbakir Air Base, Turkey. Testing and evaluation was performed on 28 April 1994 by CW2 John Hall, Project Executive Office Division, Aviation Electronic Combat, St. Louis, Missouri, and SSG Freddie Holmes, 4th Bde, 3d Infantry Division (Mech), Giebelstadt, Germany. The purpose of the testing was to determine the operational status of the aircraft, identify maintenance deficiencies, and evaluate maintenance personnel knowledge of maintenance procedures on communication and aircraft survivability equipment. Aircraft inspected were serial numbers 87-24656, 87-26001, 87-24555, 87-24634.

2 Items checked

a AN/ALQ - 144A Passive Infra Red (IR) Counter Measure System. Provides helicopter protection against 1st and 2nd generation IR missiles operating in bands 1, 2, 3, and 4. Areas covered:

(1) System Operation

(2) Jam Code Setting

(3) Air crew knowledge

(4) Unit equipment testing procedures at Aviation Unit Maintenance (AVUM) level and Aviation Intermediate Maintenance (AVIM) level.

b. M130 Chaff Dispenser system. Provides aircraft protection against radio frequency (RF) systems by dispensing RF reflective material into the atmosphere to inhibit threat radar lock, on aircraft. Areas covered:

(1) System Operation

(2) Program Salvo/Burst Setting

(3) Air crew knowledge

(4) Unit Equipment testing procedures at (AVUM) and (AVIM) level.

c AN/APR-39 A(V)1 Radar Warning Receiver System Detects RF radar signal and provides the air crew a visual display of threat radar signal Areas Covered:

- (1) System Operation
- (2) System Installation
- (3) Emitter Identification Data Version Number
- (4) Air crew knowledge
- (5) Unit Equipment testing procedures at (AVUM) and (AVTM) level

d ARC-164 HAVE QUICK I (HQI) UHF Radio. Provides UHF Amplitude Modulated air-to-air and air-to-ground radio communications and communications on Guard (emergency frequency) The ARC-164 has a HAVE QUICK mode (anti jam) which uses a frequency hopping method to change the frequency selected many times a second Areas covered:

- (1) System Operation
- (2) Air crew knowledge
- (3) Unit Equipment testing procedures at (AVUM) and (AVTM) level

e AN/APX-100 Transponder System Provides automatic radar identification of the aircraft to all suitably equipped challenging aircraft, surface and ground facilities within the operating range of the system Areas covered:

- (1) System Operation
- (2) Code Setting Procedure
- (3) Air crew knowledge
- (4) Unit Equipment testing procedures at (AVUM) and (AVTM) level.

3. Results of testing and evaluation.

a. AN/ALQ-144A (para 2a) All areas inspected were being correctly accomplished in accordance with TM 11-5865-20-12 and TM 55-1520-237-10

b. M130 (para 2b). All areas inspected were being correctly accomplished in accordance with TM 9-1095-206-23, TM 9-4940-497-13 and TM 55-1520-237-10.

c AN/APR-39 A(V)1 (para 2c) All areas inspected were being correctly accomplished in accordance with appropriate maintenance and operator manuals. However the AN/APR-39 A(V)1 self-test on aircraft 87-24634 indicated the processor failed the memory test. Eagle maintenance personnel changed processor. The AN/APR-39 A(V)1 on aircraft 87-24634 passed the self-test. Self-test will test the IPI150 display, processor, and front/rear receivers.


d ARC-164 HQI (para 2d) All areas inspected were being correctly accomplished in accordance with appropriate maintenance and operator manuals. HQI is installed on the 4 UH 60 aircraft evaluated. The F-15 aircraft and AWACS aircraft are equipped with HQII. The ARC-164 HQI is not compatible with the ARC-164 HQII, however, ARC-164 with HQII can be adjusted to be compatible at the unit level to operate with the ARC-164 HQI.

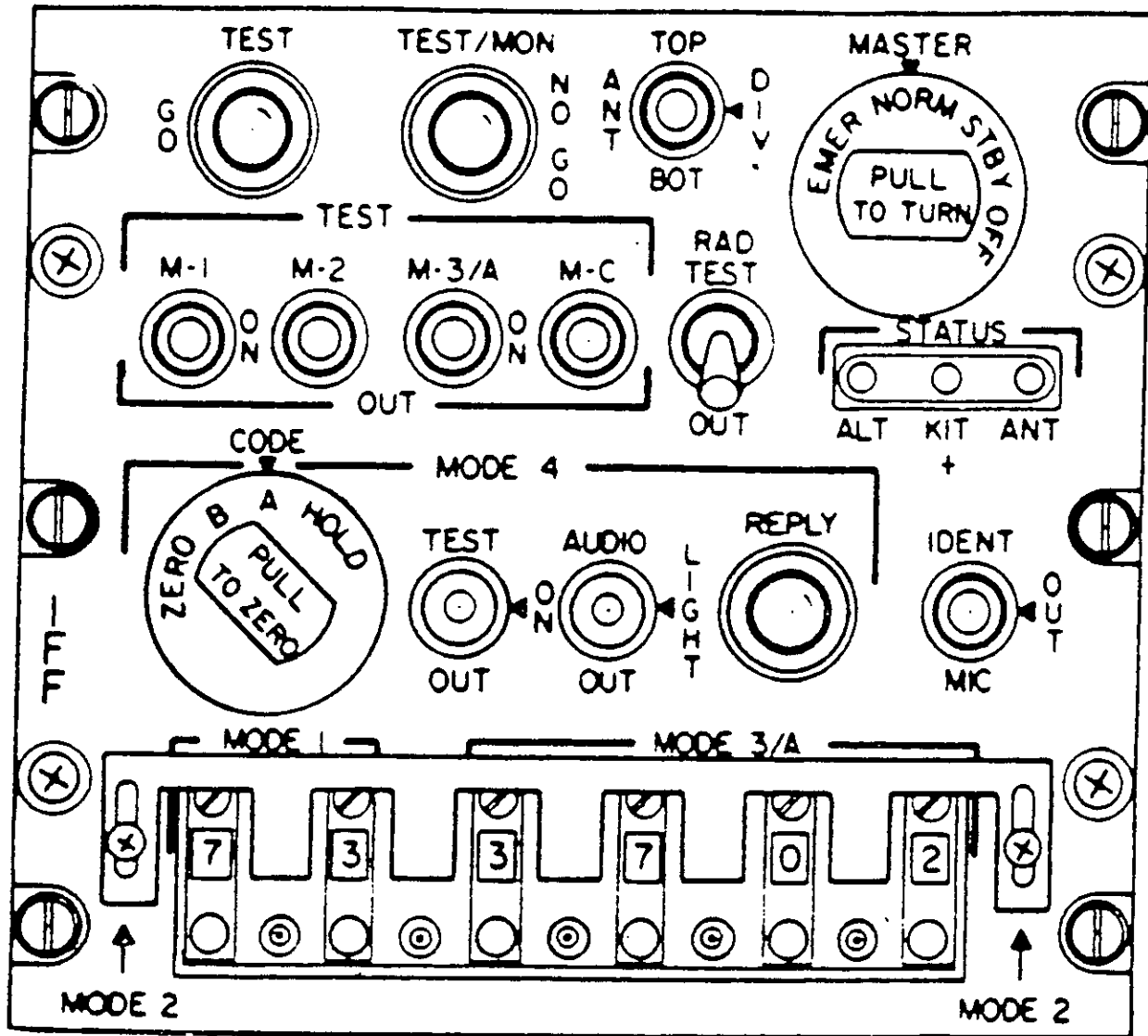
e AN/APX-100 (para 2e) All areas inspected were being correctly accomplished in accordance with TM 11-5895-1199-12 and TM 55-1520-237-10.

4. Determination.

a Prior to the repair of the AN/APR 39 A(V)1 RWR unit, communication and aircraft survivability equipment (avionics) was at a 90% operational rate. Unit had a 100 percent operational rate for avionics upon completion of inspection.

b Unit personnel were operationally knowledgeable on all communication and aircraft survivability equipment systems. System operation and maintenance status on all communication and aircraft survivability equipment was found to be correctly accomplished. The processor which failed were the only piece of equipment that was not found to be fully operational. As stated previously, it was replaced by maintenance personnel which made the system operational. There was an Army school trained Electronic Warfare Officer (EWO) who was assigned to Eagle Flight Detachment, on-board the lead UH-60 helicopter at the time of the accident. One of his responsibilities was to insure unit personnel were knowledgeable on the operation of aircraft survivability equipment.


JOHN B. HALL
CW2, USA
Aviation Technical Adviser



Transponder Control Heads

DEPARTMENT OF THE ARMY
Headquarters V Corps
Corps Aviation Safety and Standardization Detachment
APO AE 09165

AETV-AV-SS (95-1)

11 April 1994

MEMORANDUM THRU Deputy V Corps Aviation Officer

FOR V Corps Inspector General

SUBJECT: Trip Report, Operation Provide Comfort

1. Unit visited: 12th Aviation Brigade Detachment in support of Operation Provide Comfort.

2. Dates of visit: 29 March - 5 April 1994

3. Purpose of visit: Conduct on site inspection of aircraft maintenance and aircrew training.

4. Personnel from CASSD involved: MW4 Mann and MSG Wachtanz

5. Entry/Exit Briefings: Conducted entry briefing with CPT McKenna (Detachment Commander) on 31 March 1994. Conducted exit briefing with CW3 Holder (Operations Officer) and CW3 Henry (Maintenance Officer) on 4 April 1994. CPT McKenna was required out of sector on 3 and 4 April 1994.

6. Findings/Observations:

a. Maintenance:

(1) Four UH-60 aircraft historical records were reviewed. Even with personnel rotation requirements, the records were maintained efficiently. No deficiencies were noted in two aircraft records. Four minor discrepancies, details at enclosures 1 through 4 (Tab A), were noted in two of the aircraft records.

(2) Aircraft six month files were well maintained with no deficiencies noted.

(3) Three aircraft equipped with the Auxiliary Fuel Monitoring System were inspected with no deficiencies. Aviators responded that the system is very dependable.

(4) In May 1994, the Detachment will lose a highly qualified person (MOS 76Y) to maintain tech supply. Additionally, the Detachment will soon convert to the Unit Level Logistics System-Aviation (ULLS-A) computer system and this will require that a highly qualified individual is available to establish and maintain the new system.

AETV-AV-SS (95-1)

SUBJECT: Trip Report, Operation Provide Comfort

(5) MW4 Mann conducted pre-flight inspection on three aircraft and flew two of the aircraft. All aircraft inspected were very clean and appeared well maintained. Both the Detachment maintenance personnel and the Serv-Air personnel distinguished themselves by their response time for maintenance assistance during mission preparations. Appropriate personnel should be commended for their efforts to ensure that the aircraft were on time and mission capable.

b. Flight Standardization/Aircrew Training Program:

(1) Per the recommendation of the CASSD, the Commander C/6-159th Avn Regt is maintaining all Individual Aircrew Training Folders (IATF) at the unit's home base. Inspection of IATFs was completed for this unit 9-14 January 1994.

(2) Both the mission SOP and the Night Vision Goggle (NVG) SOP were reviewed. Both SOPs were well written with clear and concise directive information to conduct both the mission and NVG training. NVG training and operational requirements established in the SOP are in compliance with current DA, USAREUR, and V Corps NVG directives and guidance.

(3) The inspection team was provided the opportunity to participate on a flight mission. Individual flight evaluations were not conducted. CPT McKenna, WO1 Garrett, CW3 Holden, and their crew chiefs/gunners should be commended for a highly professional and safe mission accomplishment. During a very fluid environment, from the mission briefing through the mission debriefing all crew members demonstrated only professional concern for mission accomplishment with no deterioration of safety.

7. Operational Observations:

a. The 12th Avn Bde currently has one liaison officer (LNO) on station at Incirlik Air Base. 1LT Geis should be commended for his exceptional coordination efforts for the team's visit. 1LT Geis exhausted all means in an attempt to keep the team on schedule and provided the team with indispensable assistance.

b. The Combined Task Force (CTF) Commander has established a minimum enroute altitude of 4,500 feet above ground level (AGL) for the Low Level Transit Routes (LLTR) that the Eagle Flight Detachment utilizes. The team was briefed that this altitude restriction was established to provide protection from the small arms threat environment.

AETV-AV-SS (95-1)

SUBJECT: Trip Report, Operation Provide Comfort

c. The interpretation of the current Air Coordination Order (ACO) requires the aircraft to accomplish an extreme rate of descent upon arrival and maximum climb rates at the Turkey/Iraq border.

d. Mission aircraft are not configured with long range communication equipment.

e. Mission aircraft are currently configured with the Trimble Navigation Trimpack global positioning system (GPS) equipment.

f. Mission aircraft are currently configured with the External Range Fuel System (ERFS).

8. RECOMMENDATIONS:

a. That the 5-158th Avn Regt and the 12th Avn Bde assist C/6-159th Avn Regt in providing the flight detachment with a highly qualified individual to convert to the ULLS-A system and to ensure that the tech supply is continued to be maintained in an appropriate manner. Another option, that the 12th Avn Bde may consider, is adjusting the Serv-Air contract for an additional individual to perform these functions.

b. That the 12th Avn Bde consider providing an assistant LNO at Incirlick Air Base. Many of the observed LNO duties kept 1LT Geis out of the office. Attempts of telephone communication were many times delayed due to these 'out of office' requirements. A senior NCO (SSG or above) should provide sufficient manpower requirements to maintain communication and assist with the numerous duties being performed by this office.

c. That V Corps coordinate with USEUCOM and CTF to consider lowering the minimum enroute altitude on the LLTR from 4,500 feet AGL to 2,000 feet AGL. See enclosure 5 (Tab B) for detailed discussion and rationale.

d. That V Corps coordinate with USEUCOM and CTF to change the ACO to read that descents may commence at turn point four on the LLTR to no less than 2,000 feet AGL at the Turkey/Iraq border and that, on return, a minimum altitude of 2,000 feet AGL be achieved at the Turkey/Iraq border with the cruising enroute altitude of 8,500 feet mean sea level (MSL) achieved at turn point 4 with weather permitting. See enclosure 6 (Tab C) for detailed discussion and rationale.

AETV-AV-SS (95-1)

SUBJECT: Trip Report, Operation Provide Comfort


e. That V Corps assist the 12th Avn Bde and the 5-158 Avn Regt in obtaining long range radio communication for the Detachment aircraft, either Satellite Communication (SATCOM) or High Frequency (HF) communication equipment. See enclosure 7 (Tab D) for detailed discussion and rationale.

f. That V Corps assist the 12th Avn Bde and the 5-158th Avn Regt in obtaining an integrated GPS navigational system for the Detachment aircraft. See enclosure 8 (Tab E) for detailed discussion and rationale.

g. That 12th Avn Bde and the 5-158th Avn Regt consider replacing or augmenting the ERFs with the internal 'Robinson' extended range fuel system. That V Corps assist in obtaining the required system(s). See enclosure 9 (Tab F) for detailed discussion and rationale.

h. That CPT McKenna, CW3 Holden, and the members of both the rear and forward Military Coordination Center (MCC) be commended for their extraordinary efforts to ensure that the inspection team was afforded every opportunity to review all aspects of the Eagle Flight Detachment's operation.

9 Encls
as


LEON A. MANN, JR.
MW4(P), USA
Team Chief

CF (w/encls):
CDR, 12th Avn Bde
✓ CDR, 5-158th Avn Regt
CDR, C/6-159th Avn Regt
DET CDR

LINE-OF-SIGHT PROPAGATION

Radio-wave propagation has an inherent role in all applications of communications and electronic countermeasures. Radiations must be propagated through space occupied by the earth's atmosphere. Various atmospheric constituents make propagation a dynamic and at times critical consideration. Line-of-sight propagation deals with propagation between two points lying within line-of-sight of each other. Line-of-sight propagation is affected by absorption, dispersion, and refraction. Line-of-sight Absorption is the literal absorption of power by certain atmospheric constituents. **ALL OF THE ABSORPTION MECHANISMS ARE FREQUENCY SENSITIVE.** Two general categories are molecular absorption and ionospheric absorption. Line-of-sight Dispersion is distortion of a signal owing to the fact that the velocity of propagation is a function of frequency. Therefore, the phase relationships between high-frequency components and low-frequency components may differ resulting in a distorted waveform. Two general categories are Tropospheric Dispersion and Ionospheric Dispersion. Dispersion is a function of the effects of absorption. Line-of-sight Refraction relates to the bending of the electromagnetic waves. The bending can give rise to an apparent direction of arrival which differs from the true direction in which a source lies. It is possible for electromagnetic waves to follow two or more different paths between a transmitter and receiver thus causing constructive or destructive interference resulting in strengthened or weakened signals respectively. This multipath delay effectively reduces the bandwidth which propagation can support and thus leads to distortion of wideband signals (such as narrow pulses). Two general categories are Tropospheric Refraction and Ionospheric Refraction.

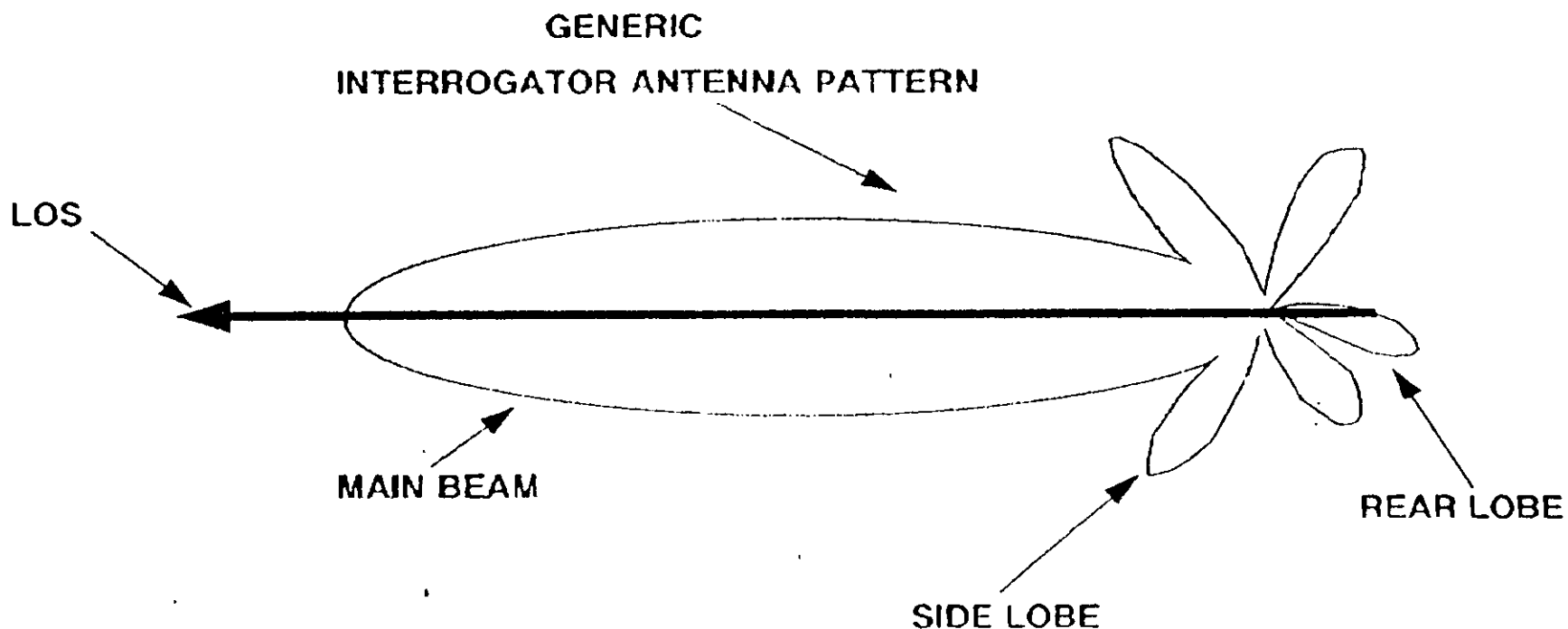
Therefore, there are limits to the reach of electromagnetic signals. At frequencies normally used for radar, radio waves usually travel in a straight line. The signals are influenced by the effects stated above.

ELECTRONIC COUNTERMEASURES

Peninsula Publishing
 Published May 1976

Editors: J. A. Boyd
 D. B. Harris
 D. D. King
 H. W. Welch, Jr.

GENERIC INTERROGATOR LINE OF SIGHT (LOS)



THE INTERROGATOR LINE OF SIGHT (LOS) IS DETERMINED BY THE AXIS OF THE MAIN BEAM OF THE INTERROGATOR ANTENNA AS INSTALLED ON THE USING PLATFORM. THE DIRECTION OF THE LOS IS NORMALLY ALIGNED WITH THE WEAPONS TARGETING AND/OR SIGHTING SYSTEM SUCH THAT THE TARGET BEING ENGAGED IS THE BEING INTERROGATED.



DEPARTMENT OF THE ARMY
PROJECT MANAGER, AVIATION ELECTRONIC COMBAT
4300 GOODFELLOW BOULEVARD, ST. LOUIS, MO 63120-1798



REPLY TO
ATTENTION OF

SFAE-AV-AEC

20 May 1994

MEMORANDUM FOR ACCIDENT INVESTIGATION BOARD

SUBJECT: Discussion of Interrogator and Fire Control Radar (FCR) Interaction.

1. The interrogator line of sight is controlled by the fire control radar (FCR) which must point the interrogator main beam at the target being queried. Aside from the potential loss of line of sight due to obstruction caused by the mountainous terrain and relative low level of the targets, failure of the fire control radar to achieve and maintain a solid lock of the target aircraft could also cause a loss of line of sight or could have resulted in failure to correlate response and interrogation.

2. The FCR used on the F-15 involved in this incident was the AN/APG-63. This is the original radar supplied with this aircraft and is one of the first if not the first FCR to achieve a look-down shoot-down capability. It is a multimode pulse doppler radar designed primarily for engaging high speed (i.e. narrow doppler spread) targets. In this aircraft the AN/APX-76 interrogator system is slaved to the FCR line of sight. The FCR uses the target doppler to track the target and point the interrogator. Targets are identified in the FCR computer by their doppler. For fixed wing targets operating at high speed and at altitudes that place ground clutter doppler out of the FCR main beam, the doppler signature is fairly distinctive and covers a narrow doppler frequency spread. For slow moving low altitude rotary wing targets however, the doppler signature is dominated by rotor doppler of the helicopter not the body doppler caused by the aircraft motion. Additionally with targets close to the terrain the FCR main beam will be picking up a doppler return from the terrain resulting from the relative motion of the ground to the speed of the F-15 creating doppler clutter from which the FCR must pick out the slow moving helicopter. Radars such as the AN/APG-63 will have difficulty locking on to slow moving targets in this situation at altitudes of 150 feet or lower. Formation flight of the helicopters also complicates the situation because the rotors doppler signature which will dominate tend to cancel in the center (i.e. passage of rotors moving in opposite directions). The resulting target doppler picture presented to the FCR computer will be characterized by a broad doppler spectrum which will be varying making it difficult for the FCR computer to identify it as a single doppler target and result in a poor lock.

3. The APX-76 incorporates a mode IV automatic evaluator which supplies mode IV reply information to the FCR computer to be correlated with the doppler of the target that the FCR and APX-76 believe sent the mode IV reply. In the event that the FCR has a number of potential doppler targets (e.g. from a broad spectrum target) at the same or nearly the same range the FCR will not be able to correlate a valid mode IV reply with the targets doppler. In This situation without a solid lock the APX-76 could present a no reply to the pilot even though there was a valid reply. If the FCR did not have a solid lock on the target when the interrogator sent its interrogation the FCR would not be able to correlate the reply to the target.

SFAE-AV-AEC

SUBJECT: Discussion of Interrogator and Fire Control Radar (FCR) Interaction

In this situation when the APX-76 receives a reply it requests the FCR to verify that the reply was from that target. If the FCR had shifted to another target because it did not have a solid lock it would declare that the reply did not come from the same "doppler target" it had interrogated. The APX-76 reply evaluator would present a no reply to the pilot.

4. The above discussion simplifies in the extreme a very complex situation and can not conclusively determine that this is in fact what happened to cause a failed response to valid mode IV interrogations when there is every indication that there were also valid mode IV replies being transmitted by the aircraft. The discussion does however present a possible explanation of what could have caused a failed response. A more detailed analysis of the situation is being conducted by both Navy and Air Force experts on these systems and will be supplied as soon as completed.

5. Point of contact on this matter is Mr. William Nicholson, DSN 693-5534 or commercial (314) 263-5534.



THOMAS E. REINKOBER
Colonel, Aviation
Project Manager
Aviation Electronic Combat

STATEMENT OF QUALIFICATIONS

I am CW2 John B. Hall, assigned to the Project Executive Office Project Manager Aviation Electronic Combat (PM AEC), St. Louis, MO as an electronic warfare officer. I am a technical advisor to the AFR 110-14 Accident Board investigating the crash of two US Army Black Hawk helicopters and the possible involvement of US fighter aircraft in the crash of these helicopters in northern no-fly zone of Iraq on 14 Apr 94. I have attended the Navy Electronic warfare course at Pensacola Naval Air Station and the Multi-Spectral Electronic Warfare course at George Washington University. I have served 2 years as a electronic warfare officer at battalion and brigade level. I have served 2 years as an assistant program manager at PM AEC with the task of training electronic warfare officers and assisting in the development of advanced electronic warfare equipment.

14 MAY 94
(DATE)

John B. Hall
JOHN B. HALL, CW2, USA

**AFR 110-14 AIRCRAFT ACCIDENT BOARD
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**O
P**

3 May 94

MEMORANDUM FOR DEPUTY BOARD PRESIDENT

SUBJECT: Property Damage

1. An assessment of private property damaged at the accident sites of the two Black Hawk helicopters is:

a. Site #1 (MF177698)

- An onion field, approximately 50' by 100' in size
- Scorched ground, approximately 150' by 100' in size, caused by aircraft fire
- Gouges in the ground due to the impact of the aircraft
- Approximately 3 trees (about 8' high) burned by the aircraft fire
- Fuel spill that killed vegetation in several places ranging from 30 feet to several feet in length along the right side of the ridge line (along the flight path)
- Pollution of ground and stream at point of impact from fuel, oil, hydraulic fluid, and composite materials (aircraft debris)

b. Site #2 (MF193703)

- Scorched ground, approximately 100' by 100' in size
- Three (3) trees cut in half (originally 8' high) by the aircraft's rotor blades
- Gouges in the ground due to the impact of the aircraft
- Approximately 10 trees (ranging from 5' to 8' high) burned by the aircraft fire
- Pollution of ground and stream near the point of impact by fuel, oil, hydraulic fluid, and composite materials (aircraft debris)

2. This assessment was conducted by myself and CW5 Dan Medina of the US Army Safety Center on 26 Apr 94.



LENEAR ROYER, Lt Col, USA
Technical Advisor

MEMORANDUM FOR ACCIDENT INVESTIGATION BOARD/ Lt/Col Lawler

FROM: Captain James E. Hurley, MCC Contracting Officer

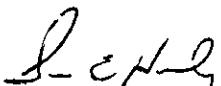
SUBJECT: Estimation of Damage Caused by the Two Helicopters

1. Presently I am Squadron Commander at Goodfellow AFB TDY to Zakho Iraq as the MCC Contracting Officer. My background. I have an undergraduate degree in engineering and an MBA. My first three years I was a navigator in a C-130, then medically grounded. My last eight years I have been in the acquisition career field.

2. A claim for \$100.00 to pay the land owner was negotiated and paid immediately after the crash for site one. The climate/tension and the need to have the local community work with the coalition to provide security and help with the immediate clean-up prompted a quick amiable settlement. I feel the amount paid was fair and reasonable to both parties.

3. The helicopter crash at site two in my estimation caused no financial burden to the land owner. The steep hill was not tillable therefore unusable as an income producing property.

4. Actual pollution seemed to be held to a minimum. The first people on the site stated to the best of their knowledge all the liquids (fuel, oil etc..) burned immediately.


JAMES E. HURLEY
Captain, USAF
MCC Contracting Officer

MEMORANDUM FOR RECORD

20 APRIL 1994

SUBJECT: PAYMENT FOR DAMAGES


1. Farmer approached our interpreter (Shafik Taha Ahemed) concerning the damages to his farm land. Mr. Ahemed asked the farmer (Mr. Mohammed Amin Khorhid) what a reasonable price would be to compensate his damages.

- Damage to onion field and crop \$50.00 U.S. dollars
- Removal of helicopter parts \$30.00 U.S. dollars
 - Any debris after investigation on his land affecting his farming
- Damage to fence/support structure \$20.00 U.S. dollars

TOTAL \$100.00 U.S. dollars

2. To verify this farmer actually owned the land Mr. Ahemed inquired within the local community. All the responses came back affirmative, Mr. Khorshid does own the land.

3. Mr. Ahemed contacted me with the above information and asked what to do. Considering the situation I felt an immediate settlement to be prudent. The settlement is fair and reasonable. The farmer became more amiable to working with the coalition in terms of tying up his land for an extended period of time.


JAMES E. HURLEY, CAPT, USAF
MCC, CONTRACTING OFFICER

MEMORANDUM FOR RECORD

16 APRIL 1994

SUBJECT: PAYMENT FOR DAMAGES

1. FINANCIAL DAMAGES TO Mohammed Amin Khorshid ONION FIELD AND PAYMENT FOR REMOVAL OF THE HELICOPTER IS SUMMARIZED BELOW.

DAMAGE TO ONION FIELD AND CROP 50 \$

COST OF REMOVAL OF HELICOPTER PARTS 30 \$

ADDITIONAL COSTS (SPECIFY BELOW) 20 \$



2. PAYMENT OF THIS DAMAGE CLAIM CONSTITUTES FINAL PAYMENT FOR THIS MATTER; FARMER AGREES THAT NO ADDITIONAL CLAIM WILL BE SUBMITTED TO THE US OR ANY OTHER COALITION GOVERNMENT.

SIGNATURE OF FARMER

Mohammed Amin Khorshid

NAME OF FARMER

SIGNATURE OF US REP

Shafiq Taha Ahmed

NAME OF US REP

SIGNATURE OF WITNESS

Suleman Mikail

NAME OF WITNESS

Damage to Field fence
\$10000
supporting
el.

**AFR 110-14 AIRCRAFT ACCIDENT BOARD
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